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Outcome Line
SBA-1

Improved Beans for the Developing World

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

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PRODUCT LINE LOGFRAME

IMPROVED BEANS FOR THE DEVELOPING WORLD: PRODUCT LINE SBA1

Rationale & Changes

Rationale

The common bean (*Phaseolus vulgaris* L.) is the world's most important grain legume for direct human consumption. Its total production exceeds 12 million MT, of which 7 million MT are produced in tropical Latin America and Africa. Beans are the "poor man's meat" and are particularly important in the diet of the underprivileged. Beans, like other legumes, supply proteins, carbohydrates, vitamins and minerals, and complement cereals, roots and tubers that compose the bulk of diets in most developing countries.

Common bean is also one of the most diverse crops in terms of its cultivation methods and its uses. It serves as mature grain, as immature seed, and as a vegetable (both leaves and pods), and after harvest the stover is used as animal fodder. It is cultivated from sea level up to 3000 masl in monoculture, in association, or in rotations. The possibility of obtaining a harvest in as little as two months offers quick income, quick food supply, and also permits rotating with other crops or inter-planting among fruit trees or coffee before the primary crop produces income. At the other extreme are the aggressive climbing beans that subsistence farmers maintain in the garden for food security and continual harvest over a six month period.

Apart from subsistence cultivation, beans have become increasingly commercial over the past thirty years in national, regional and international markets. In Central America beans are the #1 income generator among the traditional field crops. In Africa, farmers tap into regional bean markets in Nairobi, Kinshasa and Johannesburg. With the onset of globalization, the past decade has seen a growing international market that is now reported to reach 2.4 million MT. This heightens issues of equity for the small bean producers that have little other stable source of income, but some also see this as an opportunity. For example, bean represents 6% of external income for Ethiopia, and small farmers in Bolivia produce the large white and red mottled classes for export. Snap beans are a high value, labor intensive crop of small farmers in Kenya and the Andes.

Besides the common bean, another four cultivated species are conserved in the CIAT gene bank, as well as wild relatives. This collection is the largest of the genus in the entire world, representing more than 35,000 accessions that have been declared as part of the designated collection before FAO. These other cultivated species fill niches that are unsuitable for the common bean, for example, *P. acutifolius* that thrives in desert environments.

Our primary mission is to contribute to household and global food security by assuring an adequate supply of beans as a culturally acceptable and traditional staple; and to improve the income of small bean producers of Latin America and Africa, by making bean production more profitable. We also seek to improve human nutrition, both by augmenting the supply of beans, and by improvement of their nutritional value.

Our products are designed to respond in particular to the needs of small, resource-poor bean farmers in Latin America and Africa. Thus, we seek to create solutions to biotic and abiotic production limitations that require minimal inputs, and in the case of improved germplasm, with good market potential. **Our research strategy** focuses on the exploitation of the vast genetic resources of bean that exist as a complex array of major and minor gene pools, races and sister species. CIAT's gene bank with 41,000 accessions of common bean and related species is our most unique resource, and has been the source of genes for disease and insect resistance, abiotic stress tolerance, nutritional quality and yield potential. Most traits are still selected by conventional means in field sites (in some cases backed up by greenhouse evaluations) where most important diseases, edaphic constraints and drought can be manipulated for purposes of selection. However, Marker Assisted Selection (MAS) is employed selectively but strategically, in most cases for disease resistance genes. CIAT pioneered participatory selection with farmers and this practice is being extended and systematized. While most products are seed based, others involve agronomic practices or are knowledge based. Our research is strategic combined with both basic and applied elements, as called for by the particular challenge.

Changes

There have been no essential changes in relation to the MTP of 2007. However, in 2008 an agricultural economist, Dr. Enid Katungi came on board under the Tropical Legumes-II project, with base in Kampala, Uganda.

CG System Priorities

CIAT's bean product line is housed principally under CG System Priority Area 2: Producing more and better food at lower cost through genetic improvements. Efforts are dedicated to improving yields through control of diseases and pests, tolerance to abiotic stresses (drought, aluminum toxicity and low soil fertility in particular), and expanding the adaptation range of climbing beans. The bean product line also places heavy emphasis on improvement of nutritional quality, especially through increase in iron and zinc content in the grain. There is potential to contribute to Priority Area 3A: Increasing income from fruits and vegetables, through the improvement of snap beans for both Africa and Latin America. The bean team collaborates with marketing specialists to create varieties with better market potential, including international export markets (Priority Area 5B). Finally, strengthening national institutions (Priority Area 5A) continues to be an important product, both in Africa where novel institutional arrangements and relations have been productive to achieve wide impact, and in Latin America where staff reductions have weakened national programs. On both continents national programs seek support to incorporate modern selection techniques.

Impact Pathways

Product 1 (Beans with improved micronutrient concentration that have a positive impact on human health) is targeted to small farmers and poor rural and urban consumers in Africa and Latin America. Targeting is developed in collaboration with nutritionists and with experts in GIS, to address human populations with nutritional deficiencies in iron and zinc. This product involves both small seeded germplasm that is often targeted to warmer climates or more difficult environments in Central America, Mexico, Venezuela, East Africa and Brazil. Large seeded germplasm is usually cultivated in more temperate climates in the Andean zone, the East African highlands and southern Africa, although in the African highlands small and large seeded types overlap, sometimes differentiated by soil fertility gradients within the farm, prevailing biotic constraints and household preferences. Improved germplasm is shared or developed jointly with NARS partners, who supply basic seed to a range of organizations interested in production of seed (local seed companies, NGO's, CBO's, women's groups) who in turn distribute to farmers. NGOs and health workers play a special role in delivery. Benefits accrue to farmers/consumers through stable food supply of more nutritious beans for home consumption, and potentially to poor urban consumers. Assumptions for the successful delivery of these products include institutional and financial stability of partners, political stability, and institutional support. The role of CIAT is that of a primary research provider (of improved germplasm), at times a secondary research provider (backing up national bean improvement programs with technical expertise and training), and catalyser (to promote downstream alliances in the uptake chain). This product is complementary to those of CIMMYT and CIP.

Beneficiaries of ***Product 2*** (Beans that are more productive under low input agriculture of poor farmers) are in some cases researchers (both inside and outside of CIAT), and in some cases are bean producers. For example, molecular markers for resistance genes benefit researchers directly, and farmers indirectly as subsequent beneficiaries. Uptake pathway for such methodologies is direct communication through workshops and courses, and indirectly through publications, leading to benefits of more efficient and effective bean research. This assumes that partners are in a position to implement such technologies. On the other hand, crop management practices are of direct benefit to farmers as users, potentially across all bean ecosystems. Uptake chains for agronomic practices are similar to those for seed based technologies; results are communicated to NARS and other partners (NGO's, CBO's etc) who have successfully diffused practices to farmers, to the benefit of farmers who enjoy more stable productivity. Improved germplasm is diffused through many of the same channels as beans with improved nutritional value, with the exception that partners may have less specific interests, and may be more production oriented. The role of CIAT is that of primary source of research for development.

Product 3 (Beans that respond to market opportunities) benefit small farmers in both Latin America and Africa. Farmers in Ethiopia have already benefited from tapping into export markets for canning beans, and other countries are positioning themselves to follow suite. In Central America exporters are seeking to fill a niche created by the Latin population in the USA. This is a demand-driven activity, and in large part has generated its own impact pathway. Exporters and international grain buyers have established market chains that give them access to export quality beans. CIAT's role has been that of supplying germplasm in some cases, and in others to facilitate communication, and to give support in seed systems to avail quality seed to farmers of very specific varieties.

Product 4, (Strengthened institutions that enhance product quality and delivery) seeks to benefit partners at multiple levels through facilitated interaction, including farmers who are at the end of the organizational chain. NGOs, government extension agencies, farmer organizations, local seed companies, and non-conventional seed actors such as women groups, people living with HIV/AIDS and tobacco companies all participate and benefit. The product will generate impact on target beneficiaries through their participation in development of innovations, knowledge and technologies in strategic alliances with multidisciplinary research teams and NGOs. Scaling out of innovations and best practices to areas with similar environments will be done through strategic alliances of research and development actors. The latter will use their network and other communications mechanism to adapt knowledge and results relevant to them. Scaling up regionally and internationally will be done through international NGOs, advocacy, and communication. The outcome is enhanced communication and complementarity of actors with resulting cost efficiencies, and in the case of technology diffusion, increased and diversified adoption. Another dimension of this product is support to NARS in development of projects, benefiting national program researchers and with the outcome of their integration into the product line research mode. This assumes a degree of consistency in partner personnel, while CIAT's role is that of facilitator.

International Public Goods

The IPG of the bean product line include:

- Improved germplasm with biotic and abiotic stress tolerance, and/or enhanced nutritional value, drawing upon the genetic resources of CIAT's extensive gene bank, and 30 years of experience in bean improvement. CIAT's geographical position and access to varied altitudes and research sites facilitates study and selection of germplasm.
- Improved practices for the management of pests and diseases, including monitoring of pathogen populations with modern molecular tools developed at CIAT.
- Knowledge and tools that contribute to the development and implementation of the above IPG's. For example, molecular markers for useful traits, developed with CIAT's in-house resources of genetic maps and markers. Knowledge of the structure of genetic resources housed

in the gene bank, and ways to exploit them. Screening methods to identify biotic and abiotic stress resistant genotypes. Participatory breeding methods with varying degrees of involvement of farmers, traders and other key actors.

- Methods for networking, both formal among official sector researchers, and less formal among a broader range of partners, with special emphasis on research partnerships and on effective and sustainable seed systems reaching a large number of households.

Partners

Most important partners and the respective person-years of professionals dedicated to bean research within the (several) products are:

Product 1: NARS in Latin America, including those of Mexico (6), Guatemala (2.5), Honduras (2, including EAP-Zamorano), El Salvador (2), Cuba (2), Brazil (4) participate in the AgroSalud project to improve nutritional quality and productivity of bean. NARS in South America, including those of Colombia (5 between university staff, an NGO and the NARI), Bolivia (4 between university staff and a foundation) collaborate in the improvement of disease resistance of Andean bean with better nutritional quality, also under the AgroSalud project. NARS in East, Central and Southern Africa, including those of Kenya (5), Rwanda (6), Uganda (5), Malawi (1), Zimbabwe (1) are partners in the improvement of nutritional qualities in large seeded Andean beans. Linkage funds finance a project with one Canadian university, and with a partner in USDA.

Product 2: Nicaragua (4.5) and Honduras (2) are partners in breeding for drought tolerance. NARS in East, Central and Southern Africa including those of Ethiopia (3), Kenya (2), Tanzania (3), Rwanda (4), Malawi (1), Zimbabwe (1) and DRCongo (4), participate in the improvement of productivity under low soil fertility and/or drought. The University of Hannover, Germany participates in a project to define physiological mechanisms of aluminum tolerance and drought resistance (2), which also includes Malawi (2) and Rwanda (4). Catholic University of Leuven (3) is a partner to improve nitrogen fixation technology. NARS in South America, including those of Colombia (5 between university staff, an NGO and the NARI), Bolivia (4 between university staff and a foundation) collaborate in the improvement of disease resistance of Andean bean. NARS in East, Central and Southern Africa, including those of Kenya (5), Rwanda (6), and Uganda (5) Tanzania (4) are partners in the development of disease resistance, medium altitude climbing beans (MAC), and productivity in large seeded Andean beans. NARS in Honduras (Zamorano) (1), Colombia (2), Uganda (3), Rwanda (4), and South Africa (2) share in the use of markers for MAS, especially for resistance. South Africa (3) participates in pathogen characterization, evaluation and validation of resistance sources. Agriculture and Agri-Food Canada (AAFC) is a partner in diagnosis and characterization of soil borne pathogens (especially *Pythium* species) using molecular techniques, and development of molecular based diagnostic assays for soil borne pathogens.

Product 3: Partners in Latin America with specific attention to breeding market quality include NARS in Honduras and Nicaragua. NARS in Africa with active participation in canning beans include those of Ethiopia and Uganda. Partners in the development of snap beans include a university in Colombia, and one in Kenya.

Product 4: NARS as above –plus a wide range of NGOS, CBOS, farmers' groups, women's groups, – totaling over 300 direct-link partnerships, to make users aware of technologies and to get these technologies widely disseminated.
The ECABREN and SABRN bean networks coordinate nine NARS in East Africa and ten NARS in southern Africa, respectively. These networks participate in Products 1, 2, 3 and 4 with input from African NARS cited above, plus NARS in Burundi (3), Sudan (2), Zambia (1), Zimbabwe (1), Mozambique (3), Lesotho (3) and Swaziland (3).

HarvestPlus Challenge Program: IFPRI, CIMMYT, and CIP are immediate collaborators in the CP and the AgroSalud (Latin American) nutritional improvement project, working in the same agro-ecological zones, while ICRISAT, IITA, IRRI, and ICARDA are indirect collaborators under HarvestPlus. ECABREN and SABRN networks in Africa also participate in HarvestPlus.

Generation Challenge Program: Partners include EMBRAPA-Brazil (2), INTA-Cuba (1), Pairumani (an NGO) in Bolivia (2), National University in Colombia (2).

Sub-Saharan Africa Challenge Program: ICIPE, AHI and NARS in Rwanda, Uganda and D.R. Congo are immediate partners.

Product line Funding

Budgeting 2007-2011

Year	**2007 (actual)**	**2008 (actual)**	**2009 (proposal)**	**2010 (plan)**	**2011 (plan)**
US Dollars (millions)	8.008	9.931	7.597	7.702	7.812

IMPROVED BEANS FOR THE DEVELOPING WORLD: PRODUCT LINE SBA1 (2008-2010)

Targets	Products	Intended User	Outcome	Impact
PRODUCT 1	Beans with improved micronutrient concentration that have a positive impact on human health	NARS, farmers & consumers in Central America, the Caribbean, Brazil, East and Southern Africa	Adoption of improved varieties by farmers	Better nutritional status, especially of rural consumers
Product Targets 2008	• ~30 small seeded F3-derived F5 bush bean families developed with tropical adaptation, 60% more minerals, abiotic stress tolerance, and 2 biotic resistances for Central America (HarvestPlus)	• NARS, NGO's CBO's, health workers, and farmers in target countries	• Farmers incorporate high mineral and disease resistance lines into diverse production systems	• Reduced levels of iron and zinc deficiency in bean consumers
Product Targets 2009	• 50 improved lines with varietal potential and 90 ppm iron (ie, 80% more iron) • 15 new large seeded climbing beans with high mineral trait (HarvestPlus) • Marker assisted selection for one nutritional trait (iron) tested	• NARS, NGO's CBO's, health workers, and farmers in target countries	• Adoption of micronutrient rich beans	• Reduced levels of iron and zinc deficiency in bean consumers
Product Targets 2010	• Four fast track micronutrient dense bean varieties disseminated and promoted in two countries in eastern and southern Africa • Two large seeded lines with 50% more iron enter formal varietal release process in eastern Africa	• NARS, NGO's CBO's, health workers and consumers	• Adoption of micronutrient rich beans	• Reduced levels of iron and zinc deficiency in bean consumers

Targets	Products	Intended User	Outcome	Impact
PRODUCT 2	Beans that are more productive in smallholder systems of poor farmers	Breeders and pathologists in CIAT and NARS; farmers in E and S Africa, Andean zone, Caribbean	Adoption of improved varieties by farmers; Best bet IDPM practices and genetic combinations for stable resistance deployed.	More stable production, food availability and income
Product Targets 2008	• 5 molecular markers for detection, diagnosis and diversity studies of ALS and anthracnose pathogens made available • At least 10 lines in major market classes combining resistance to Pythium root rots, BCMV and angular leaf spot • An IPM system for whiteflies on snap beans refined and promoted in 2 major bean producing areas of the Andean zone	• NARS, NGO's and farmers' groups • CIAT and NARS breeders • NARIs researchers in LAC, Africa, IARCs	• Disease and pest characterization tools adopted by researchers • Adoption of disease resistant lines in marginal environments • Increased utilization of integrated management approaches.	• Improved food security, & income. • More stable disease resistance in advanced lines leads to stable yield
Product Targets 2009	• An IDM system for bean root rots implemented and promoted in 2 major bean producing countries in Africa • At least 40 lines combining drought resistance with resistance to BCMNV, root rots, and/or ALS available for testing in Africa • 2 molecular markers linked to ALS and Pythium root rot implemented in MAS	• NARS breeders, NGO's, CBOs, and farmer groups • NARS pathologists,	• Resistant lines incorporated into improved systems • Drought resistant lines with disease resistance used in drought prone areas in Africa • Breeders improve efficiency of genetic improvement	• Reduced yield losses from ALS, root rots and drought
Product Targets 2010	• Resistance genes for anthracnose or ALS introgressed into 5 BCMNV resistant climbing beans • At least 10 genotypes combining drought resistance with aluminium resistance available for testing in Africa	• NARS breeders, NGO's, CBOs, and farmer groups • NARS soil scientists and agronomists	• Farmers benefit from yield stability of high yield climbers • Farmers benefit from stable yields in marginal areas	• Improved food security, & income.

Targets	Products	Intended User	Outcome	Impact
PRODUCT 3	Beans that respond to market opportunities	NARS in Africa and Latin America	Adoption of commercial varieties by farmers, enhancing access to markets	Higher income, especially for the poor and women farmers
Product Targets 2008	• 10 lines of snap beans with confirmed resistance to Gemini virus in Colombia • 1 variety released in Nicaragua for export market	• NARS, NGOs, CBOs, farmer groups, seed producers	• Farmers reduce pesticide use, assuring production and profitability	• Less pesticide intoxication in rural communities and urban consumers • Increased production and incomes.
Product Targets 2009	• At least 3 snap bean lines with resistance to rust and quality characteristics preferred in regional and export markets for Africa. • 4 bean genotypes with very high commercial or export quality made available to farmers in 4 countries in Latin America and Africa	• NARS, NGOs, CBOs, farmer groups, seed producers	• Adoption of snap bean and reduced chemical use. • Farmers in marginal environments assure market access	• Increased production and incomes.
Product Targets 2010	• 5 canning bean lines with acceptable quality characteristics in yield trials in two countries in eastern Africa	• NARS, NGOs, CBOs, farmer groups, seed producers	• Farmers improve yields and quality of product with improved varieties	• Increased production and incomes.

Targets	Products	Intended User	Outcome	Impact
PRODUCT 4	Strengthened institutions that enhance bean product development and delivery	NARS in Africa and Latin America	Improved institutional performance by NARS, NGOs and other partners, reflected in more effective technology development and dissemination	More stable production, improved food availability, income and nutrition, especially for the poor and women farmers
Product Targets 2008	• One comprehensive methodology developed for assessing seed security and targeting responses in acute and chronic stress situations. • Lessons from 3 case studies (approaches for partnership; capacity building; alternative seed delivery systems) of strategies for product development and delivery in PABRA analyzed. • Protocols developed and adapted to facilitate application of MAS for disease resistance in 3 African countries • Breeding programs for higher iron levels established in Honduras, Nicaragua, Bolivia, Venezuela, Kenya and Malawi	• NARS, NGOs, CBOs, farmer groups, seed certification agencies, seed producers • UN, humanitarian and post-stress recovery organizations • PABRA	• Frameworks and methodologies for seed systems, PM&E, and MAS are in use by PABRA partners	
Product Targets 2009	• A guide for mainstreaming and sustaining wider impact, developed and recommendations availed for 5 countries in East, Central and 4 countries in Southern Africa • Three delivery channels strategies tested for reaching the poor and in marginal areas with new variety innovations and information • At least 1 methodological frameworks/strategies for testing and evaluating multi-stakeholder networks and platforms (between private-public) for facilitating decentralized targeting for pro poor impact.	• NARS, NGOs, Decentralized Local Governments, CBOs, farmer groups, seed certification agencies, seed producers ,agro-processors, local financial institutions • UN, humanitarian and post-stress recovery organizations	• Increased partner involvement in accessing technologies to a greater number of end users • Increased capacities of partner organizations / institutions to develop and promote integrated and decentralized strategies for reaching pro-poor farmers	

Targets	Products	Intended User	Outcome	Impact
	• Capacity to evaluate root systems in soil tubes established in Honduras and Nicaragua			
Product Targets 2010	• Elements of Pro-poor seed delivery and production systems confirmed and such pro-poor seed enterprises established in 2 PABRA network countries. • One strategy for wider utilization of non varietal bean technologies (IPM; soil management) developed and widely shared in 4 countries in Africa	• NARS, NGOs, CBOs, farmer groups, seed certification agencies, seed producers		
PRODUCT 5	More than 35,000 accessions are conserved, documented and available for distribution	Breeders, geneticists, and other bean scientists; national gene banks	Bean genetic resources are used directly or employed in breeding programs	More stable production, improved food availability, income and nutrition
Product Targets 2008	• 1500 accessions conserved in long term storage and in back-up in CIMMYT • 1000 samples of bean seed distributed	• Bean scientists; other gene banks	• Novel genes incorporated into breeding programs	
Product Targets 2009	• Another 1500 accessions conserved in long term storage and in back-up in CIMMYT • Another 1000 samples of bean seed distributed • A plan formulated to establish a database of evaluation data	• Bean scientists; other gene banks	• Novel genes incorporated into breeding programs	
Product Targets 2010	• Another 1500 accessions conserved in long term storage and in back-up in CIMMYT • Another 1000 samples of bean seed distributed	• Bean scientists; other gene banks	• Novel genes incorporated into breeding programs	

Product 1: Beans with improved micronutrient concentration that have a positive impact on human health

Activity 1.1 Developing more nutritious bean varieties

Highlights:

- More than 30 F_{3-5} small seeded Mesoamerican families were selected for high mineral concentration and some degree of drought resistance.
- Eighteen lines derived from interspecific crosses were coded as MIB (high mineral) lines, with levels of iron above those of the high iron check MIB 465. Some also have superior resistance to foliar pathogens.
- Over 200 pollinations were generated combining multiple sources of resistance to diseases and drought with high mineral (Fe and Zn) content in SABRN countries.
- Some good donor parent for drought resistance in common bean (SEA5, SEA15 and SER16) were also good parents for high Fe and Zn content.
- Several populations combining different market classes and disease or drought resistance, but also with high mineral (Fe and Zn) content have been generated, and some may have high Fe and or Zn content. Four bush and three climbing micronutrient dense bean varieties with high yield potential are pre-released for smallholder production in eastern Africa. This marks the first time biofortified mineral dense bean varieties are formally recommended for release following independent evaluations.
- Bioavailability of Fe in raw samples of fast track bean lines varies from 1.1% to 6.6%.
- Bioavailability of Zn in raw samples of fast track lines varies from 0.5 to 2.5%.
- Cooking enhances Fe and Zn bioavailability in beans by more than two fold.
- Freshly shelled beans have more bioavailable Fe and Zn compared with dry beans.

Actvity 1.2 Genotype x environment interaction

Highlights:

- NUA35 and NUA56 were tested for yield potential and mineral accumulation across 15 sites in Latin America (72 replicates), showing that both lines have a 15 to 25 ppm differential iron advantage over CAL96.
- Significant genotype x environment interactions indicate that grain mineral concentration is influenced by soil type, soil nutrient status, moisture concentration and other environmental factors but the magnitude varies with genotypes. Some genotypes show high stability for mineral density.
- Fertilization regimes and other agronomic practices can be used to enhance expression of high mineral density traits.

Activity 1.3 Associated traits: antinutrients

Highlights:

- The inheritance of seed phytate content was analyzed to determine if this anti-nutrient could be reduced and how it is related to seed phosphorus content. Quantitative inheritance was found with several QTL explaining both traits independent of seed size. The results of this study show some genotypes with low levels of phytates which would seem to be sufficient for breeding attempts. The other anti-nutrient being analyzed is condensed tannins and an HPLC method was adapted to look at the tannin monomers that accumulate in genotypes from an inter-genepool population.

Product 2: Beans that are more productive in smallholder systems of poor farmers

Activity 2.1 Developing germplasm tolerant to abiotic stresses

2.1.1 Drought resistance

Highlights:

- Mesoamerican crosses among drought resistant parents that had expressed a degree of tolerance to low soil P availability, produced more than 20 lines that were excellent in drought resistance. Some lines subsequently showed adaptation to low P in Darién, producing grain of excellent quality under combined drought and low P stress.
- Another 15 Mesoamerican families combined drought tolerance and *bc*-3 gene for resistance to BCMNV.
- In an effort to incorporate drought tolerance in Andean bush beans we have created a series of 216 advanced drought Andean beans (DAB) lines from inter and intra-gene pool crosses involving 5 commercial genotypes from Southern Africa and 10 drought tolerance sources of which half were Andean and half were Mesoamerican to produce 46 populations. The lines represent large red, red mottled and cream mottled seed types. Selection has stressed bush bean architecture, adaptation to drought stress and yield potential under favorable conditions using alternate dry versus rainy season plantings.
- A reference collection of landraces from the CIAT core collection has been evaluated in the field for drought tolerance compared to a series of check genotypes. The reference collection was stratified into Andean and Mesoamerican gene pools and the association of drought tolerance with subgroups and common bean races was analyzed.
- Mid-elevation adaptation was tested in Darién for a series of SAB (drought resistant Andean) lines originally developed from crosses between the drought-resistant genotypes SAB 258, SAB 259, and ICA Quimbaya crossed with drought susceptible but commercial type genotypes ABA36, ABA58 and COS16. Results confirmed the genetic gain for drought tolerance and yield potential that has occurred in the breeding of the SAB lines compared to both their drought-tolerant and susceptible parents. The same lines were tested in rainfed conditions in Palmira and several maintained their yield advantage over local checks. Certain SAB lines can be selected with greater stability across mid-elevation and lower-elevation sites based on this analysis.
- Field evaluation of elite lines at Palmira resulted in identification of five lines NCB 226, SEN 56, SER 113, SER 125 and SER 16 that were outstanding in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of harvest index, pod harvest index, leaf area index and canopy biomass. The SER lines that were developed in the last few years seem to combine the desirable traits for drought adaptation such as greater mobilization of photosynthates to seed with efficient use of water through stomatal control.
- Field evaluation of 33 RILs of the cross DOR 364 x BAT 477 at Palmira over two seasons under terminal drought stress conditions resulted in identification of two lines (BT 21138-17-1-1 and BT 21138-6-1-1) that were superior in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of harvest

index, pod harvest index and seed and pod number per area indicating the importance of greater mobilization of photosyntates to pods and to seeds under rainfed conditions.

- Field evaluation of 97 RILs of the cross DOR 364 x BAT 477 under intermittent drought stress resulted in identification of two RILs BT 21138-68-1-1 and BT 21138-74-1-1 that were outstanding in adaptation to intermittent drought stress conditions. The superior performance of these lines under intermittent drought stress was associated with higher values of harvest index, pod partitioning index, stem biomass reduction, seed number per area and pod number per area indicating the importance of greater mobilization of photosyntates to pods and seeds under rainfed conditions.
- Field evaluation of 121 RILs of the cross MD 23-24 x SEA 5 over 3 seasons resulted in identification of the lines MR 81 and MR 25 that were superior in adaptation to drought stress conditions. The superior performance of these lines was associated with higher vigor, higher values of pod harvest index, harvest index and seed number per area, highlighting the importance of the photosyntate mobilization to pods and seeds under intermittent drought stress.
- The response to inoculation with the strain *Rhizobium etli* CIAT 632 under drought stress was tested using 7 common bean genotypes. We found that Pinto Villa was better adapted to drought due to its ability to decrease stomatal conductance while Alubia cerrillos was more affected due to drought stress. Although there was no response to inoculation, the effect of terminal drought stress on nodulation was very marked on all 7 genotypes.

2.1.2 Aluminum resistance

Highlights:

- Lines derived from an interspecific cross of SER 16, a drought resistant line, by *Phaseolus coccineus* (G35346) yielded well under both rainfed and aluminum toxic conditions. Some actually yielded more in intermittent drought than SER 16.
- SER 16 proved to be an excellent common bean parent to cross with *P. coccineus*, perhaps due to its characteristic of excellent remobilization to grain.
- A filter paper-styrofoam sandwich germination method was developed to improve the phenotyping capacity for Al resistance in common bean and a primary root marking method was developed to evaluate short-term effects of Al on root elongation process.
- A method was adapted and validated for screening for aluminum resistance in common bean based on qualitative determination of aluminum-complexing compounds including citrate released from the roots.
- Phenotypic evaluation of 20 common bean genotypes for aluminium resistance confirmed the higher level of Al resistance of three Andean genotypes (ICA Quimbaya, BRB 198 and G5273) and identified one Mesoamerican genotype (G24601) also with higher level of Al resistance.
- Phenotypic evaluation of 97 RILs of DOR 364 x BAT 477 for aluminium resistance resulted in identification of a few RILs with low inhibition of root growth under high Al in solution. Two RILs (BT 21138-128-1-M-M-M and BT 21138- 2-1-1-M-M-M) were found to be outstanding in root growth both with and without aluminum in solution.

Activity 2.2 Developing germplasm with resistance to insect pests: Bruchids and leafhopper

Highlights:

- New accessions from the gene bank were evaluated for insect resistance
- Resistance to *Zabrotes subfasciatus* was reconfirmed
- New breeding lines that have resistance to the leafhopper (*Empoasca kraemeri*) were identified

- Some Andean bean lines presented high level of tolerance to *Empoasca* and less yield loss

Activity 2.3 Developing germplasm resistant to disease

Highlights:

- A large number of crosses were made to pyramid insect (bruchid) and disease (BCMNV and CBB) resistance with drought tolerance or mid-elevation adaptation in Andean bush beans. The arcelin gene was used as the source of bruchid resistance and was effectively selected for in 115 different cross combinations. Meanwhile, 187 cross combinations were generated for disease resistance. These crosses are being advanced at our drought stress and mid-elevation sites in Colombia.
- Twelve new, large seeded red mottled bean varieties with multiple resistance to diseases and up to 30% better yield compared to commercial varieties released in six countries in eastern Africa.
- Thirteen new red kidney varieties combining multiple stress resistance with high yield potential and marketable grain characteristics are released in seven countries in east and central Africa.
- Eight new speckled sugar varieties with multiple disease resistance, marketable grain types and high yield potential (up to 24% over commercial checks) released for smallholder production in four countries in eastern Africa.
- Eight new small and medium red bean varieties combining multiple disease resistance, high yield potential and marketable grain characteristics released for smallholder production in three countries of eastern Africa.
- Eighteen new tan, brown and yellow seed varieties with multiple resistance to diseases and high yield potential released for production by smallholder farmers in four countries in eastern Africa
- Twenty-six new climbing bean varieties combining multiple resistances to diseases with high yield potential and marketable grain characteristics released for smallholder production in seven countries in east and central Africa.
- Several segregating populations and fixed lines in different market classes from South Africa, Malawi and Tanzania are available for distribution to interested NARS partners within SABRN and others in Africa
- From the regional breeding program 24 (brown/khaki), 73 (sugar) and 213 (red mottled) developed for resistance to angular leaf spot, or common bacterial blight or low soil fertility or a combination of these stresses were distributed to various NARS programs.
- Twenty-nine lines in various market classes which were developed for rust resistance or a combination of rust and angular leaf spot or rust and halo blight resistance by the NARS in South Africa were sent to the SABRN coordinator for seed increase and onward distribution to other interested NARS for the next planting season.
- Twenty four new lines with a resistance gene to *Pythium* root rot were identified and included in the *Pythium* root rot nursery.
- Forty lines combining resistance to *Pythium* root rot and angular leaf spot were identified and available for sharing with partners

Activity 2.4 Yield potential: climbing beans

Highlights:

- QTL for growth habit and climbing ability were identified on six chromosomes, although many were located on B04. This illustrates the complexity of growth habit, and implicitly, of crop domestication as growth habit was reduced from climbing to bush type.

Activity 2.5 Characterizing and monitoring pathogen and insect diversity

Highlights:

- Sixteen *Pythium* species were found to be associated with beans root rots in Rwanda and the cultivars CAL 96, RWR 617-97A, Urugezi and RWR 1668 were susceptible to all these species. G2331, AND 1062, MLB-40-89A, Vuninkingi, AND 1064 and RWR 719 were resistant.

Activity 2.6 Developing integrated disease and pest management components

Highlights:

- All of the bean-planted areas in Colombia and Ecuador included in the Fontagro-financed project "Reduction in the Use of Pesticides and Development of Resistance in Rice and Common Bean Crops in Colombia, Venezuela and Ecuador" were monitored for white fly populations.
- Whitefly species and biotypes, thrips and leafminers were identified, patterns of pesticide use for whitefly, thrips and leafminers registered, and levels of pesticide resistance in whitefly, thrips, and leafminer populations in Colombia quantified.
- *Psuedomonas sp* were isolated and shown to have antagonistic effects on *Pythium spp*
- Genetic diversity of varietal mixtures from southwest Uganda was characterized with indications of its potential value in the region.

Product 3: Beans that respond to market opportunities

Activity 3.1 Development of large white beans for international markets

Highlights:

- Crosses have been developed to combine alubia grain type (uniform, milky white, long cylindrical seed) with drought resistance.

Activity 3.2 Breeding Navy and Large White bean varieties with multiple stress resistance in eastern Africa

Highlights:

- Fourteen new navy and large white bean varieties combining multiple resistance to diseases and abiotic stress factors, high yield potential and marketable grain characteristics released for smallholder production in four countries in eastern Africa

Activity 3.3 Identification of a varietal candidate in Nicaragua with potential for international export

Highlights:

- The bean program of INTA-Nicaragua has selected a line for varietal release with the purpose of exporting grain to the USA.

Activity 3.4 Progress in development of Snap and runner beans for smallholder production in East and Central Africa

Highlights:

- Twenty bush and climbing snap bean lines with consumer preferred pod characteristics and resistance to diseases selected in four countries in eastern Africa.
- Nineteen new short-day runner bean lines with high pod yield potential selected making smallholder production under short-day conditions in eastern Africa feasible.

Product 4: Strengthened institutions that enhance bean product development and delivery

Activity 4.1 Strengthened capacity of NARS: increasing the knowledge and skills of scientists and staff from NARIs, NGOs and Rural Service Providers

Highlights:

- A total of forty-nine students conducted research activities related to their thesis work, of which twenty eight were at CIAT HQ, and twenty one in Africa. Of these, three PhD and one MSc students were as visiting researchers at HQ.
- In Latin America, two M.Sc. candidates, and two pre-graduate students completed their research theses. In Africa three PhD, four M.Sc. and one Bs. candidates completed their research theses.
- A total of thirty-three students continue their studies, as follows: six Ph.D. candidates in Africa and five in Latin America, eight M.Sc. candidates in Africa and four in Latin America, and ten pre-graduate in Latin America.
- Twelve visiting researchers coming from Colombia, Cuba, Denmark, Guatemala, Hungary, India, Panama and Zambia received training in different disciplines at headquarters.
- Several courses and workshops were held in Latin America and Africa
- During this reporting period there was a joint stakeholders meeting for PABRA partners, as well as a joint steering committee meeting for SABRN and ECABREN where they reflected on the progress over the past 4 years, and planned activities to achieve the milestones contributing towards achieving the goals in the final year of the project, as well as to plan for the next phase.
- A number of students have either registered or started their course work at various universities to sharpen their knowledge and skills in bean research for development. Two new students doing MSc in plant breeding enrolled at the University of Zambia and Penn State University, both from Malawi. Two other students had been accepted for Ph.D. programs at the University of Free State and Massey University – New Zealand. These scientists will add to the existing capacity for bean research in the region.

Activity 4.2 Strengthen international collaboration through networks (Intra- and inter-network collaboration), bi-lateral relations, and/or joint special projects

Highlights:

- The Pan African Bean Research Alliance (PABRA) continued to provide funding support to research for development sub-projects within the SABRN

Activity 4.3 Supporting breeding programs in NARS, regional networks, farmers' Associations, and CIALs with germplasm and technical knowledge

Highlights:

- More fixed lines with high yield potential and resistance to diseases and cultivars of commercial value for export market were distributed in a regional yield trial to various NARIs partners in different countries.
- Early generation selections of interspecific crosses for high iron have been realized in ICTA, Guatemala and are pending shipment to CIAT for analysis.
- Selections from EAP-Honduras have been analyzed and returned to the breeder there.
- High iron lines are in validation trials in Nicaragua and a variety could be released in the course of 2009.

Activity 4.4 Development of sustainable seed systems to support wide dissemination

Highlights:

- A strategy of marketing small seed packets as a profitable enterprise is being developed with a private seed company in Kenya and shows great promise for reaching thousands of bean growers.
- An analysis of the effectiveness of training in seed production suggests that participants have significantly improved both technical and communication skills.
- A seed security assessment methodology has found acceptance at the institutional level among important players such as FAO, USAID and important international NGO's.

Activity 4.5 Socio-economic activities

Highlights:

- A baseline study to determine the role of beans in drought prone areas of eastern Kenya has been completed. Beans are the second most important food after maize and are critical for food security.

EXECUTIVE SUMMARY

ANNUAL REPORT 2008

Outcome Line

SBA-1

Improved Beans for the Developing World

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

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1. PRODUCT LINE LOGFRAME

IMPROVED BEANS FOR THE DEVELOPING WORLD: PRODUCT LINE SBA1

Rationale & Changes

Rationale

The common bean (*Phaseolus vulgaris* L.) is the world's most important grain legume for direct human consumption. Its total production exceeds 12 million MT, of which 7 million MT are produced in tropical Latin America and Africa. Beans are the "poor man's meat" and are particularly important in the diet of the underprivileged. Beans, like other legumes, supply proteins, carbohydrates, vitamins and minerals, and complement cereals, roots and tubers that compose the bulk of diets in most developing countries.

Common bean is also one of the most diverse crops in terms of its cultivation methods and its uses. It serves as mature grain, as immature seed, and as a vegetable (both leaves and pods), and after harvest the stover is used as animal fodder. It is cultivated from sea level up to 3000 masl in monoculture, in association, or in rotations. The possibility of obtaining a harvest in as little as two months offers quick income, quick food supply, and also permits rotating with other crops or inter-planting among fruit trees or coffee before the primary crop produces income. At the other extreme are the aggressive climbing beans that subsistence farmers maintain in the garden for food security and continual harvest over a six month period.

Apart from subsistence cultivation, beans have become increasingly commercial over the past thirty years in national, regional and international markets. In Central America beans are the #1 income generator among the traditional field crops. In Africa, farmers tap into regional bean markets in Nairobi, Kinshasa and Johannesburg. With the onset of globalization, the past decade has seen a growing international market that is now reported to reach 2.4 million MT. This heightens issues of equity for the small bean producers that have little other stable source of income, but some also see this as an opportunity. For example, bean represents 6% of external income for Ethiopia, and small farmers in Bolivia produce the large white and red mottled classes for export. Snap beans are a high value, labor intensive crop of small farmers in Kenya and the Andes.

Besides the common bean, another four cultivated species are conserved in the CIAT gene bank, as well as wild relatives. This collection is the largest of the genus in the entire world, representing more than 35,000 accessions that have been declared as part of the designated collection before FAO. These other cultivated species fill niches that are unsuitable for the common bean, for example, *P. acutifolius* that thrives in desert environments.

Our primary mission is to contribute to household and global food security by assuring an adequate supply of beans as a culturally acceptable and traditional staple; and to improve the income of small bean producers of Latin America and Africa, by making bean production more profitable. We also seek to improve human nutrition, both by augmenting the supply of beans, and by improvement of their nutritional value.

Our products are designed to respond in particular to the needs of small, resource-poor bean farmers in Latin America and Africa. Thus, we seek to create solutions to biotic and abiotic production limitations that require minimal inputs, and in the case of improved germplasm, with good market potential. **Our research strategy** focuses on the exploitation of the vast genetic resources of bean that exist as a complex array of major and minor gene pools, races and sister species. CIAT's gene bank with 41,000 accessions of common bean and related species is our most unique resource, and has been the source of genes for disease and insect resistance, abiotic stress tolerance, nutritional quality and yield potential. Most traits are still selected by conventional means in field sites (in some cases backed up by greenhouse evaluations) where most important diseases, edaphic constraints and drought can be manipulated for purposes of selection. However, Marker Assisted Selection (MAS) is employed selectively but strategically, in most cases for disease resistance genes. CIAT pioneered participatory selection with farmers and this practice is being extended and systematized. While most products are seed based, others involve agronomic practices or are knowledge based. Our research is strategic combined with both basic and applied elements, as called for by the particular challenge.

Changes

There have been no essential changes in relation to the MTP of 2007. However, in 2008 an agricultural economist, Dr. Enid Katungi came on board under the Tropical Legumes-II project, with base in Kampala, Uganda.

CG System Priorities

CIAT's bean product line is housed principally under CG System Priority Area 2: Producing more and better food at lower cost through genetic improvements. Efforts are dedicated to improving yields through control of diseases and pests, tolerance to abiotic stresses (drought, aluminum toxicity and low soil fertility in particular), and expanding the adaptation range of climbing beans. The bean product line also places heavy emphasis on improvement of nutritional quality, especially through increase in iron and zinc content in the grain. There is potential to contribute to Priority Area 3A: Increasing income from fruits and vegetables, through the improvement of snap beans for both Africa and Latin America. The bean team collaborates with marketing specialists to create varieties with better market potential, including international export markets (Priority Area 5B). Finally, strengthening national institutions (Priority Area 5A) continues to be an important product, both in Africa where novel institutional arrangements and relations have been productive to achieve wide impact, and in Latin America where staff reductions have weakened national programs. On both continents national programs seek support to incorporate modern selection techniques.

Impact Pathways

Product 1 (Beans with improved micronutrient concentration that have a positive impact on human health) is targeted to small farmers and poor rural and urban consumers in Africa and Latin America. Targeting is developed in collaboration with nutritionists and with experts in GIS, to address human populations with nutritional deficiencies in iron and zinc. This product involves both small seeded germplasm that is often targeted to warmer climates or more difficult environments in Central America, Mexico, Venezuela, East Africa and Brazil. Large seeded germplasm is usually cultivated in more temperate climates in the Andean zone, the East African highlands and southern Africa, although in the African highlands small and large seeded types overlap, sometimes differentiated by soil fertility gradients within the farm, prevailing biotic constraints and household preferences. Improved germplasm is shared or developed jointly with NARS partners, who supply basic seed to a range of organizations interested in production of seed (local seed companies, NGO's, CBO's, women's groups) who in turn distribute to farmers. NGOs and health workers play a special role in delivery. Benefits accrue to farmers/consumers through stable food supply of more nutritious beans for home consumption, and potentially to poor urban consumers. Assumptions for the successful delivery of these products include institutional and financial stability of partners, political stability, and institutional support. The role of CIAT is that of a primary research provider (of improved germplasm), at times a secondary research provider (backing up national bean improvement programs with technical expertise and training), and catalyser (to promote downstream alliances in the uptake chain). This product is complementary to those of CIMMYT and CIP.

Beneficiaries of ***Product 2*** (Beans that are more productive under low input agriculture of poor farmers) are in some cases researchers (both inside and outside of CIAT), and in some cases are bean producers. For example, molecular markers for resistance genes benefit researchers directly, and farmers indirectly as subsequent beneficiaries. Uptake pathway for such methodologies is direct communication through workshops and courses, and indirectly through publications, leading to benefits of more efficient and effective bean research. This assumes that partners are in a position to implement such technologies. On the other hand, crop management practices are of direct benefit to farmers as users, potentially across all bean ecosystems. Uptake chains for agronomic practices are similar to those for seed based technologies; results are communicated to NARS and other partners (NGO's, CBO's etc) who have successfully diffused practices to farmers, to the benefit of farmers who enjoy more stable productivity. Improved germplasm is diffused through many of the same channels as beans with improved nutritional value, with the exception that partners may have less specific interests, and may be more production oriented. The role of CIAT is that of primary source of research for development.

Product 3 (Beans that respond to market opportunities) benefit small farmers in both Latin America and Africa. Farmers in Ethiopia have already benefited from tapping into export markets for canning beans, and other countries are positioning themselves to follow suite. In Central America exporters are seeking to fill a niche created by the Latin population in the USA. This is a demand-driven activity, and in large part has generated its own impact pathway. Exporters and international grain buyers have established market chains that give them access to export quality beans. CIAT's role has been that of supplying germplasm in some cases, and in others to facilitate communication, and to give support in seed systems to avail quality seed to farmers of very specific varieties.

Product 4, (Strengthened institutions that enhance product quality and delivery) seeks to benefit partners at multiple levels through facilitated interaction, including farmers who are at the end of the organizational chain. NGOs, government extension agencies, farmer organizations, local seed companies, and non-conventional seed actors such as women groups, people living with HIV/AIDS and tobacco companies all participate and benefit. The product will generate impact on target beneficiaries through their participation in development of innovations, knowledge and technologies in strategic alliances with multidisciplinary research teams and NGOs. Scaling out of innovations and best practices to areas with similar environments will be done through strategic alliances of research and development actors. The latter will use their network and other communications mechanism to adapt knowledge and results relevant to them. Scaling up regionally and internationally will be done through international NGOs, advocacy, and communication. The outcome is enhanced communication and complementarity of actors with resulting cost efficiencies, and in the case of technology diffusion, increased and diversified adoption. Another dimension of this product is support to NARS in development of projects, benefiting national program researchers and with the outcome of their integration into the product line research mode. This assumes a degree of consistency in partner personnel, while CIAT's role is that of facilitator.

International Public Goods

The IPG of the bean product line include:

- Improved germplasm with biotic and abiotic stress tolerance, and/or enhanced nutritional value, drawing upon the genetic resources of CIAT's extensive gene bank, and 30 years of experience in bean improvement. CIAT's geographical position and access to varied altitudes and research sites facilitates study and selection of germplasm.
- Improved practices for the management of pests and diseases, including monitoring of pathogen populations with modern molecular tools developed at CIAT.
- Knowledge and tools that contribute to the development and implementation of the above IPG's. For example, molecular markers for useful traits, developed with CIAT's in-house resources of genetic maps and markers. Knowledge of the structure of genetic resources housed in the gene bank, and ways to exploit them. Screening methods to identify biotic and abiotic stress resistant

genotypes. Participatory breeding methods with varying degrees of involvement of farmers, traders and other key actors.

- Methods for networking, both formal among official sector researchers, and less formal among a broader range of partners, with special emphasis on research partnerships and on effective and sustainable seed systems reaching a large number of households.

Partners

Most important partners and the respective person-years of professionals dedicated to bean research within the (several) products are:

Product 1: NARS in Latin America, including those of Mexico (6), Guatemala (2.5), Honduras (2, including EAP-Zamorano), El Salvador (2), Cuba (2), Brazil (4) participate in the AgroSalud project to improve nutritional quality and productivity of bean. NARS in South America, including those of Colombia (5 between university staff, an NGO and the NARI), Bolivia (4 between university staff and a foundation) collaborate in the improvement of disease resistance of Andean bean with better nutritional quality, also under the AgroSalud project. NARS in East, Central and Southern Africa, including those of Kenya (5), Rwanda (6), Uganda (5), Malawi (1), Zimbabwe (1) are partners in the improvement of nutritional qualities in large seeded Andean beans. Linkage funds finance a project with one Canadian university, and with a partner in USDA.

Product 2: Nicaragua (4.5) and Honduras (2) are partners in breeding for drought tolerance. NARS in East, Central and Southern Africa including those of Ethiopia (3), Kenya (2), Tanzania (3), Rwanda (4), Malawi (1), Zimbabwe (1) and DRCongo (4), participate in the improvement of productivity under low soil fertility and/or drought. The University of Hannover, Germany participates in a project to define physiological mechanisms of aluminum tolerance and drought resistance (2), which also includes Malawi (2) and Rwanda (4). Catholic University of Leuven (3) is a partner to improve nitrogen fixation technology. NARS in South America, including those of Colombia (5 between university staff, an NGO and the NARI), Bolivia (4 between university staff and a foundation) collaborate in the improvement of disease resistance of Andean bean. NARS in East, Central and Southern Africa, including those of Kenya (5), Rwanda (6), and Uganda (5) Tanzania (4) are partners in the development of disease resistance, medium altitude climbing beans (MAC), and productivity in large seeded Andean beans. NARS in Honduras (Zamorano) (1), Colombia (2), Uganda (3), Rwanda (4), and South Africa (2) share in the use of markers for MAS, especially for resistance. South Africa (3) participates in pathogen characterization, evaluation and validation of resistance sources. Agriculture and Agri-Food Canada (AAFC) is a partner in diagnosis and characterization of soil borne pathogens (especially *Pythium* species) using molecular techniques, and development of molecular based diagnostic assays for soil borne pathogens.

Product 3: Partners in Latin America with specific attention to breeding market quality include NARS in Honduras and Nicaragua. NARS in Africa with active participation in canning beans include those of Ethiopia and Uganda. Partners in the development of snap beans include a university in Colombia, and one in Kenya.

Product 4: NARS as above –plus a wide range of NGOS, CBOS, farmers' groups, women's groups, – totaling over 300 direct-link partnerships, to make users aware of technologies and to get these technologies widely disseminated.

The ECABREN and SABRN bean networks coordinate nine NARS in East Africa and ten NARS in southern Africa, respectively. These networks participate in Products 1, 2, 3 and 4 with input from African NARS cited above, plus NARS in Burundi (3), Sudan (2), Zambia (1), Zimbabwe (1), Mozambique (3), Lesotho (3) and Swaziland (3).

HarvestPlus Challenge Program: IFPRI, CIMMYT, and CIP are immediate collaborators in the CP and the AgroSalud (Latin American) nutritional improvement project, working in the same agro-ecological zones, while ICRISAT, IITA, IRRI, and ICARDA are indirect collaborators under HarvestPlus. ECABREN and SABRN networks in Africa also participate in HarvestPlus.

Generation Challenge Program: Partners include EMBRAPA-Brazil (2), INTA-Cuba (1), Pairumani (an NGO) in Bolivia (2), National University in Colombia (2).

Sub-Saharan Africa Challenge Program: ICIPE, AHI and NARS in Rwanda, Uganda and D.R. Congo are immediate partners.

Product line Funding

Budgeting 2007-2011

Year	**2007 (actual)**	**2008 (actual)**	**2009 (proposal)**	**2010 (plan)**	**2011 (plan)**
US Dollars (millions)	8.008	9.931	7.597	7.702	7.812

IMPROVED BEANS FOR THE DEVELOPING WORLD: PRODUCT LINE SBA1 (2008-2010)

Targets	Products	Intended User	Outcome	Impact
PRODUCT 1	Beans with improved micronutrient concentration that have a positive impact on human health	NARS, farmers & consumers in Central America, the Caribbean, Brazil, East and Southern Africa	Adoption of improved varieties by farmers	Better nutritional status, especially of rural consumers
Product Targets 2008	• ~30 small seeded F3-derived F5 bush bean families developed with tropical adaptation, 60% more minerals, abiotic stress tolerance, and 2 biotic resistances for Central America (HarvestPlus)	• NARS, NGO's CBO's, health workers, and farmers in target countries	• Farmers incorporate high mineral and disease resistance lines into diverse production systems	• Reduced levels of iron and zinc deficiency in bean consumers
Product Targets 2009	• 50 improved lines with varietal potential and 90 ppm iron (ie, 80% more iron) • 15 new large seeded climbing beans with high mineral trait (HarvestPlus) • Marker assisted selection for one nutritional trait (iron) tested	• NARS, NGO's CBO's, health workers, and farmers in target countries	• Adoption of micronutrient rich beans	• Reduced levels of iron and zinc deficiency in bean consumers
Product Targets 2010	• Four fast track micronutrient dense bean varieties disseminated and promoted in two countries in eastern and southern Africa • Two large seeded lines with 50% more iron enter formal varietal release process in eastern Africa	• NARS, NGO's CBO's, health workers and consumers	• Adoption of micronutrient rich beans	• Reduced levels of iron and zinc deficiency in bean consumers

Targets	Products	Intended User	Outcome	Impact
PRODUCT 2	Beans that are more productive in smallholder systems of poor farmers	Breeders and pathologists in CIAT and NARS; farmers in E and S Africa, Andean zone, Caribbean	Adoption of improved varieties by farmers; Best bet IDPM practices and genetic combinations for stable resistance deployed.	More stable production, food availability and income
Product Targets 2008	• 5 molecular markers for detection, diagnosis and diversity studies of ALS and anthracnose pathogens made available • At least 10 lines in major market classes combining resistance to Pythium root rots, BCMV and angular leaf spot • An IPM system for whiteflies on snap beans refined and promoted in 2 major bean producing areas of the Andean zone	• NARS, NGO's and farmers' groups • CIAT and NARS breeders • NARIs researchers in LAC, Africa, IARCs	• Disease and pest characterization tools adopted by researchers • Adoption of disease resistant lines in marginal environments • Increased utilization of integrated management approaches.	• Improved food security, & income. • More stable disease resistance in advanced lines leads to stable yield
Product Targets 2009	• An IDM system for bean root rots implemented and promoted in 2 major bean producing countries in Africa • At least 40 lines combining drought resistance with resistance to BCMNV, root rots, and/or ALS available for testing in Africa • 2 molecular markers linked to ALS and Pythium root rot implemented in MAS	• NARS breeders, NGO's, CBOs, and farmer groups • NARS pathologists,	• Resistant lines incorporated into improved systems • Drought resistant lines with disease resistance used in drought prone areas in Africa • Breeders improve efficiency of genetic improvement	• Reduced yield losses from ALS, root rots and drought
Product Targets 2010	• Resistance genes for anthracnose or ALS introgressed into 5 BCMNV resistant climbing beans • At least 10 genotypes combining drought resistance with aluminium resistance available for testing in Africa	• NARS breeders, NGO's, CBOs, and farmer groups • NARS soil scientists and agronomists	• Farmers benefit from yield stability of high yield climbers • Farmers benefit from stable yields in marginal areas	• Improved food security, & income.

Targets	Products	Intended User	Outcome	Impact
PRODUCT 3	Beans that respond to market opportunities	NARS in Africa and Latin America	Adoption of commercial varieties by farmers, enhancing access to markets	Higher income, especially for the poor and women farmers
Product Targets 2008	• 10 lines of snap beans with confirmed resistance to Gemini virus in Colombia • 1 variety released in Nicaragua for export market	• NARS, NGOs, CBOs, farmer groups, seed producers	• Farmers reduce pesticide use, assuring production and profitability	• Less pesticide intoxication in rural communities and urban consumers • Increased production and incomes.
Product Targets 2009	• At least 3 snap bean lines with resistance to rust and quality characteristics preferred in regional and export markets for Africa. • 4 bean genotypes with very high commercial or export quality made available to farmers in 4 countries in Latin America and Africa	• NARS, NGOs, CBOs, farmer groups, seed producers	• Adoption of snap bean and reduced chemical use. • Farmers in marginal environments assure market access	• Increased production and incomes.
Product Targets 2010	• 5 canning bean lines with acceptable quality characteristics in yield trials in two countries in eastern Africa	• NARS, NGOs, CBOs, farmer groups, seed producers	• Farmers improve yields and quality of product with improved varieties	• Increased production and incomes.

Targets	Products	Intended User	Outcome	Impact
PRODUCT 4	Strengthened institutions that enhance bean product development and delivery	NARS in Africa and Latin America	Improved institutional performance by NARS, NGOs and other partners, reflected in more effective technology development and dissemination	More stable production, improved food availability, income and nutrition, especially for the poor and women farmers
Product Targets 2008	• One comprehensive methodology developed for assessing seed security and targeting responses in acute and chronic stress situations. • Lessons from 3 case studies (approaches for partnership; capacity building; alternative seed delivery systems) of strategies for product development and delivery in PABRA analyzed. • Protocols developed and adapted to facilitate application of MAS for disease resistance in 3 African countries • Breeding programs for higher iron levels established in Honduras, Nicaragua, Bolivia, Venezuela, Kenya and Malawi	• NARS, NGOs, CBOs, farmer groups, seed certification agencies, seed producers • UN, humanitarian and post-stress recovery organizations • PABRA	o Frameworks and methodologies for seed systems, PM&E, and MAS are in use by PABRA partners	
Product Targets 2009	• A guide for mainstreaming and sustaining wider impact, developed and recommendations availed for 5 countries in East, Central and 4 countries in Southern Africa • Three delivery channels strategies tested for reaching the poor and in marginal areas with new variety innovations and information • At least 1 methodological frameworks/strategies for testing and evaluating multi-stakeholder networks and platforms (between private-public) for facilitating decentralized targeting for pro poor impact.	o NARS, NGOs, Decentralized Local Governments, CBOs, farmer groups, seed certification agencies, seed producers ,agro-processors, local financial institutions • UN, humanitarian and post-stress recovery organizations	• Increased partner involvement in accessing technologies to a greater number of end users • Increased capacities of partner organizations / institutions to develop and promote integrated and decentralized strategies for reaching pro-poor farmers	

Targets	Products	Intended User	Outcome	Impact
	• Capacity to evaluate root systems in soil tubes established in Honduras and Nicaragua			
Product Targets 2010	• Elements of Pro-poor seed delivery and production systems confirmed and such pro-poor seed enterprises established in 2 PABRA network countries. • One strategy for wider utilization of non varietal bean technologies (IPM; soil management) developed and widely shared in 4 countries in Africa	• NARS, NGOs, CBOs, farmer groups, seed certification agencies, seed producers		
PRODUCT 5	More than 35,000 accessions are conserved, documented and available for distribution	Breeders, geneticists, and other bean scientists; national gene banks	Bean genetic resources are used directly or employed in breeding programs	More stable production, improved food availability, income and nutrition
Product Targets 2008	• 1500 accessions conserved in long term storage and in back-up in CIMMYT • 1000 samples of bean seed distributed	• Bean scientists; other gene banks	o Novel genes incorporated into breeding programs	
Product Targets 2009	• Another 1500 accessions conserved in long term storage and in back-up in CIMMYT • Another 1000 samples of bean seed distributed • A plan formulated to establish a database of evaluation data	• Bean scientists; other gene banks	o Novel genes incorporated into breeding programs	
Product Targets 2010	• Another 1500 accessions conserved in long term storage and in back-up in CIMMYT • Another 1000 samples of bean seed distributed	• Bean scientists; other gene banks	o Novel genes incorporated into breeding programs	

2. Improved Beans for the Developing World – 2008 Output Targets

TARGETS 2008	Fully Achieved	75% Achieved	>50% Achieved	<50% Achieved	Cancelled	Deferred	EXPLANATION
PRODUCT 1 • ~30 small seeded F3-derived F5 bush bean families developed with tropical adaptation, 60% more minerals, abiotic stress tolerance, and 2 biotic resistances for Central America (HarvestPlus)	X						To be documented in 2008 Annual Report
PRODUCT 2 • 5 molecular markers for detection, diagnosis and diversity studies of ALS and anthracnose pathogens made available		X					Seven locus-specific microsatellite markers for ALS pathogen, which quickly distinguish between Andean and Mesoamerican pathogen groups were identified. Work on anthracnose was not pursued after the responsible pathologist left CIAT
• At least 10 lines in major market classes combining resistance to Pythium root rots, BCMV and angular leaf spot		X					Lines combining Pythium root rots and ALS and those with BCMVN in early generation.
• An IPM system for whiteflies on snap beans refined and promoted in 2 major bean producing areas of the Andean zone	X						Partially in 2007 report with additional documentation in 2008 Annual Report

TARGETS 2008	Fully Achieved	75% Achieved	>50% Achieved	<50% Achieved	Cancelled	Deferred	EXPLANATION
PRODUCT 3 • 10 lines of snap beans with confirmed resistance to Gemini virus in Colombia						X	Weather conditions in Colombia did not permit the build up of the white fly vector to be able to evaluate lines in the field
• 1 variety released in Nicaragua for export market		X					A new line with commercial grain type is already in commercial production for export but is not officially released.
PRODUCT 4 • One comprehensive methodology developed for assessing seed security and targeting responses in acute and chronic stress situations.	X						To be documented in 2008 Annual Report
• Lessons from 3 case studies (approaches for partnership; capacity building; alternative seed delivery systems) of strategies for product development and delivery in PABRA analyzed.	X						To be documented in 2008 Annual Report
• Protocols developed and adapted to facilitate application of MAS for disease resistance in 3 African countries		X					Protocols developed but adaptation in three countries delayed because of a delay in the start of Kirkhosue Trust supported projects (in 4 countries) which was to provide infrastructure and also support capacity development in collaboration with CIAT. This project start in 2009
• Breeding programs for higher iron levels established in Honduras, Nicaragua, Bolivia, Venezuela, Kenya and Malawi	X						To be documented in 2008 Annual Report

3. RESEARCH HIGHLIGHTS IN 2008

We will highlight 3 areas of our current research portfolio:

3.1. Drought resistance and yield potential in Andean beans

Contributors: S. Beebe, M. Blair, I. Rao, M. Grajales, C. Cajiao, F. Monserrate

Breeding for drought resistance in the small seeded Mesoamerican beans has been successful, but the large seeded Andean beans have received less attention. In 2007 and 2008 advanced breeding lines with commercial Andean grain types were tested under drought, and in 2008 the same lines were evaluated in Palmira with irrigation, and at a mid-altitude site (1400 masl) in Darién under rainfed but favorable conditions. Several lines expressed an advantage of about 50% in the drought trials over check cultivars in three grain classes (large red; cream striped; and large white) while progress in the red mottled class was more modest. Furthermore, in the irrigated plots and in the mid-altitude site, where the Andean beans normally adapt especially well, some drought tolerant lines yielded as much as a ton more than the checks. This finding is comparable to that with Mesoamerican beans, whereby drought-selected lines expressed improved yield potential, a finding that has been attributed to better remobilization of biomass from vegetative parts to grain. The current results suggest a similar trend in Andean beans. Yield improvement has been especially difficult in Andean beans, and these results may indicate a means to overcome this long term bottleneck.

3.2 Baseline study on the role and importance of common bean in drought prone areas of East Africa

Contributors: E. Katungi, L. Sperling, A. Farrow

The bean program is undertaking massive diffusion of drought resistant varieties in drought prone areas of east Africa. A socio-economic baseline survey was conducted in semi-arid areas of Kenya (Eastern province) and Ethiopia (Oromia and Southern region) to contextualize this effort and to orient the breeding for drought resistance. A total 360 farming households in 18 villages, and 120 traders along the value chain were interviewed in the two countries. In Kenya farmers integrate a diversity of crops, cropping systems and farming management practices with local ecosystems and livelihoods to cope with drought. They dry-plant their crops, make terraces to harvest water, intercrop intensively, keep livestock, invest in social capital, work outside their farms for food or wage and undertake petty trade and handcraft but still experience an average of 5 months of inadequate food supply per year. Drought is ranked the most important constraint to livelihood improvement, causing about 70% yield loss in common beans when it occurs. Nevertheless, common bean is ranked the second most important food crop after maize, with about 70% of households growing from 3 to 10 varieties simultaneously, primarily for home consumption. Household characteristics, as well as consumption and production attributes are the driving factors that underlie variety choice and extent of planting. The breeding effort should target both categories of attributes.

3.3 Application of MAS in support of the Ethiopian national bean improvement program

Contributors: M. Blair, H. Buendía, S. Beebe, T. Assefa, C. Cardona, J.M. Bueno

The arcelin seed protein is the most effective resistance factor for the storage pest of common bean, *Zabrotes subfasciatus* (Boheman). Crosses were made between arcelin-containing RAZ lines and a series of Andean and Mesoamerican beans with drought tolerance useful for Eastern and Southern Africa (Ethiopia, Kenya, Malawi, Tanzania and Zimbabwe). For Ethiopia, crosses were generated to incorporate arcelin into a drought tolerant background and then transfer that resistance/tolerance to the small white, Ethiopian variety 'Awash Melka'. Double crosses were generated with Andean types including the Malawian release CIM9314-34, the Kenyan releases KAT B1 and KAT B9 and other African cultivars such as Canadian Wonder, CAL96 and CAL143. Marker assisted selection (MAS) is applied for the arcelin gene to facilitate the pyramiding of bruchid resistance with other biotic and abiotic stress resistances. MAS was carried out using microprep DNA. For Andeans, a total of 251 F_1 plants segregated for the arcelin locus, and of these, 236 amplified with the arcelin marker. For improvement of Awash Melka, a total of 498 F_1 plants segregated for the arcelin locus in seven different pedigrees. This latter work represents support to an Ethiopian Ph.D. candidate. This represents the first application of MAS for insect resistance in common bean.

4. PROJECT OUTCOME:

Managing Bean Root Rot - A constraint Associated with Intensification in Land Use

Outcome statement: National program breeders and pathologists initiate breeding programs and select resistant lines based on information of pathogen distribution defined by CIAT pathologists.

This outcome results from an output target in CIAT's 2004-2007 MTP: "Pathogen distribution maps developed for ALS, anthracnose, Pythium and Fusarium." Results meeting this target were reported in the 2005 Annual Report (pp. 182-185). It is also associated with the target, "Improved germplasm available to NARS, regional networks, and farmers, combining better yield with disease resistance", by availing root rot resistant lines to partners in Africa (MTP 2004, 2005).

Context: Intensified land use in the highlands of Eastern and Central Africa has been associated with the increased incidence of bean root rots, a devastating disease caused by a complex of soilborne pathogens, mainly Pythium species. In 2001, over 75% of farmers reported calamitous declines in bean production associated with root rots in a survey in western Kenya districts of Kakamega and Vihiga. These districts and those of southwestern Uganda and many parts of Rwanda are typical of regions affected by root rot: farm sizes are small (average 1-2.6 ha), population densities high (404 persons /km^2 in Kakamega and 938 in Vihiga), and crop rotation near nil.

CIAT identified major Pythium species prevalent in Kenya, Rwanda and Uganda on the basis of cultural and molecular techniques. Species distribution and prevalence were mapped, including at key root rot "hot spots". This basic information was then used by breeders in East Africa to guide germplasm evaluations and varietal improvement programs. The regional breeder backstopping NARS breeding programs in East and Central Africa Bean Research Network (ECABREN) evaluated a range of germplasm representing different market classes using artificial inoculation of representative Pythium species and at a key "hot spot" in Western Kenya. A number of resistant germplasm such as AND 1055, NR 12793-8-1, NR 12631-7-1, RAB 475, DFA 52 and NM 12803-11 were identified (RF & CIAT Reports). Similarly NARS breeders from Kenya, Uganda, Rwanda, and southern Democratic Republic of Congo used the knowledge to evaluate nurseries and segregating populations for resistance to prevalent Pythium species (Musoni, et al. – *in press*; Otsyula, PhD thesis; Kimani et al, 2005; ECABREN Report; CIAT Annual reports) at respective "hot spots" (Vihiga, western Kenya; Kabale, southwest Uganda; Runyinya, Rwanda. Representative isolates (maintained at Kawanda, Uganda) were used to artificially screen germplasm from the three countries. A breeder from KARI, Kakamega, Kenya used the identified species to study the nature of resistance and mechanism of inheritance in selected sources of resistance (Otsyula, 2005 – Rockefeller meeting, PhD 2009 thesis). In addition he and his counterparts in Rwanda (ISAR) and Uganda (NARO) used the "hotspots" above and artificial inoculation of identified Pythium species to select resistant progenies from populations developed to improve root rot resistance in local bush (e.g. GLP-2, CAL 132, Urugezi) and climbing beans.

Following extensive artificial inoculations with key Pythium species (*P.ultimum var ultimum, P. salpingophorum, P. spinosum* , *P. torulosum, P. pachycaule*) and evaluations under natural conditions at "hotspots" by CIAT and NARS partners in Uganda, Rwanda and Kenya, resistant germplasm was used to constitute a root rot nursery. About 80 entries were made available to several NARS partners in Africa (Kenya, Uganda, Rwanda, DRC, Ethiopia, Malawi, South Africa, and Cameroon) (CIAT Annual Reports). These partners in turn involved farmers to evaluate the materials. As a result in Uganda, two genotypes originally from Rwanda (RWR 2075 and RWR 1946) were highly appreciated by farmers and traders in evaluations over a 2 year period. The farmers gave them local names; RWR 1946 with a large dark red seed type was named "Murwanisa" meaning 'resistant to harsh conditions' and RWR 2075 'Muzahura', meaning 'restorer' (Namayanja et al. Euphytica). These genotypes have been released in Uganda as NABE 13 (RWR 1946) and NABE 14 (RWR 2075), and have entered national performance trials in Kenya as well. In Kenya SCAM-CM80/15 has also been released.

5. LIST OF 2008 PUBLICATIONS

(includes in press, in review and submitted) - see complete list

5.1 Book chapters and books (all in English)

- Book chapters published:	6
- Book chapters in press:	4

5.2 Refereed and non-refereed journal articles

- Papers published in English:	25
- Papers in press in English:	1
- Papers in review in English:	2
- Papers accepted in English:	1
- Papers published in Spanish:	1
- Papers in review in Spanish:	2

5.3 Workshop and conference papers

- Papers in English:	28
- Papers in Spanish:	1

5.4 Proceedings, posters, abstracts, others

- Proceedings:	in English	13
- Posters:	in English	10
	in Spanish	4
- Others:	in English	4
- Media Campaign		Wires
		Online
		Broadcast
		Print

5.5 Editorial Contributions

- Scientific Committee of Agronomia Colombiana Journal
- Reviewed articles for:
  - Crop Science
  - Agroforestry Systems
  - Acta Agronomica

5.1 BOOK CHAPTERS AND BOOKS

Arora-Jonsson, Seema, Ballard, Heidi L., Buruchara, Robin, Casolo, Jennifer, Classen, Lauren, DeHose, Judy; Emretsson, Margareta; Fortmann, Louise; Halvarsson, Anne Lundgren; Halvarsson, Ewa; Humphries, Sally; Long, Jonathan; Murphree, Marshall W; Nemarundwe, Nontokozo; Olssen, Anne; Rhee, Steve; Ryen, Anna; Wilmsen, Carl; Wollenberg, Eva. 2008. Conclusions *In* Louise Fortmann (ed). Participatory Research in Conservation and Rural Livelihoods: Doing Science Together. Blackwell Publishing Ltd.

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Blair, M.W., A. Asfaw, G. Makunde. 2008. Advances for the common bean TL1 project. Presented at Tropical Legumes I meeting, 2 July.

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5.4 PROCEEDINGS, POSTERS, ABSTRACTS AND OTHERS

PROCEEDINGS

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Brochures

PABRA Outlook: Issue 3.

Media Campaign May/June 2008: Seed Aid, with, CIAT Communications unit, CG Communication Unit and Burness Communications.

Based on Seed AID work of L. Sperling, Tom Remington and other partners

Wires	Online
Asian News International (India)	Africa Science News Service
Reuters (Nature….) (which linked to Science)	Agricultural Biodiversity Blog
Broadcast	Andhranews.net (India)
BBC Network Africa	DailyIndia.com
South African Broadcasting Corporation (SABC) Channel Africa	KTIC Rural Radio Online
Print	*Malaysia Sun* Online
Hindustan Times (India)	*Nature* News
New Vision (Uganda)	NewKerala.com (India)
Bistandaktuelt (Norway)	Star Online (Malaysia)
	Thaindian.com (India)
	TopNews.in (India)
	Webindia123.com

5.5 EDITORIAL CONTRIBUTION

I.M. Rao served on the scientific committee of the editorial board of the journal, Agronomia Colombiana, and a reviewer to the journals: Crop Science, Agroforestry Systems and Acta Agronomica.

6. LIST OF SPECIAL PROJECTS

6.1 AT HEADQUARTERS

6.1.1 New proposals approved in 2008

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Biofortificación del Frijol Común (*Phaseolus Vulgaris* L.) en Panamá con Micronutrientes”	SENACYT – Panama	2008-2011	12,000	-	7,000
Improved beans for Africa and Latin America	DFID, UK	2008	120,690	-	120,690
Characterization of bean diversity in Central Europe	GCP	2008-2009	9,000	-	9,000
Dry bean improvement and marker assisted selection for diseases and abiotic stresses in Central America and the Caribbean”	GCP	2008-2009	40,120	-	40,120
Capacity Building Needs regarding the Tropical Legume I (TLI) Project	BMGF grant to GCP	2008-2009		5,904	5,904
Obtención y evaluación de *Phaseolus vulgaris* y Zea mays tolerantes a la sequía	CYTED, Spain	2008-2009	$1,000,000	-	29,906
Development of a handling system of *Bemisia tabaci* in paprika and pepper in the Cauca Valley Gracias	MADR	2008-2011	58,288		16.560
Improvement of Chitti bean in Iran. SPII, Iran	Iranian government	2008	18,423	-	18,423

6.1.2 List of ongoing special projects in 2008

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Reducing pesticide use and pesticide resistance in rice and beans in the Andean zone	FONTAGRO	2006-2009	224.000	64.276	125.152
Fighting Drought and Aluminium Toxicity: Integrating Genomics, Phenotypic Screening and	BMZ	2006-2009	€ 1,100,000	US153,907	US303,233

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Participatory Research with Women and Small-Scale Farmers to Development Stress-Resistant Common Bean and Brachiaria for the Tropics					
Biofortified Crops for Improved Human Nutrition – Harvest Plus Challenge Program (Yearly contracts)	Gates Foundation World Bank DANIDA, Denmark	2003-2008	305,000	50,000	255,000
Combating hidden hunger in Latin America: Biofortified crops with improved vitamin A, essential minerals and quality protein (AgroSalud)	CIDA	2004-2010	20,000,000	123,855	254,894
Integrated management of whiteflies in the tropics	DFID	2005 - 2008	259.788	7.849	22.864
Increasing Food Security and Rural Incomes in Eastern, Central and Southern Africa through Genetic Improvement of Bush and Climbing Beans (Headquarters component)	RF	2005-2008	US 254,000	-	10,750
Nutritional Improvement of the important pulse legume, the common bean, through the reduction of seed tannin content, for the benefits of people' diet in Africa and Latin America	CIDA/Univ. of Saskatchewan	2007-2010	CAD 225,000	US 32,102	US 34,503
TL1: Improving tropical legume productivity for marginal environments in sub-Saharan Africa (Headquarters component)	BMGF grant to GCP	2007-2010	1,867,328	115,000	473,944
TL2: Enhancing grain legumes productivity, production and income of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia (HQ component)	BMGF grant to CGIAR	2007-2010	3,454.802	1,104.056	197,701
Variedades de fríjol tolerantes al estrés abiótico de la baja fertilidad y la sequía, y a la sostenibilidad productiva y alimentaria de Centroamérica	Red-SICTA, SDC	2007- 2008	246,100	-	45,450

6.2 In Africa

6.2.1 New proposals approved in 2008

Title	Donor	Funding period	Total Amount US	Amount to partners US$	Available in 2008 US$
Supporting Nutrition and health, Food security, Environmental Stresses and Market Challenges that contribute to improve livelihood and create income resource poor small holder families in Sub –Saharan Africa	SDC	2009-2011	3.2 million	2,221,384	978,616

6.2.2 List of ongoing special projects in 2008

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
TL1: Improving tropical legume productivity for marginal environments in sub-Saharan Africa (African component)	BGMF	2007-2010	115,000		115,000
TL2: Enhancing grain legumes' productivity, production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia: Seed Systems (African component)	BGMF	2007-2010	2,866.084 1, 368,000 million seed systems	601,250	502,866
Getting back to basics: creating impact-oriented bean seed delivery systems for the poor in Malawi, Mozambique and Tanzania	McKnight Foundation	2007-2010	US$ 400,000	300,000	100,000
Improved Smallholder food Security, Nutrition and Income through Increased Production and Marketing of Climbing Beans.	McKnight Foundation	2007-2010	US$ 400,000	300,000	100,000
Fighting Drought and Aluminium Toxicity: Integrating Genomics, Phenotypic Screening and Participatory Research with Women and Small-Scale Farmers to Development Stress-Resistant Common Bean and Brachiaria for the Tropics	BMZ	2006-2009			US 63,185
Increasing Food Security and Rural Incomes in Eastern, Central and Southern Africa through Genetic Improvement of Bush and Climbing Beans (African component)	RF	2005-2008	US 254,000	-	76,739

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Supporting improved nutrition, food security and community empowerment for poverty alleviation – PABRA	SDC	2007-2008	US 944,616		944,616
Supporting improved nutrition, food security and community empowerment for poverty alleviation – PABRA III	CIDA	2003-2008	US5,298.787		2,231,057

6.2.3 Regional research subprojects under SABRN

Activity	Value	Country
1.1.1 Complete germplasm collection, characterization and mineral analysis for all accessions	1000	DRC
	3000	Zambia
1.1.2 Conduct multi-location evaluations and national performance trials	650	Angola
	500	DRC
	1500	Malawi
	600	Mozambique
	800	Swaziland
	1500	Zambia
	1000	Zimbabwe
1.1.3 Analyze candidate varieties for minerals and protein in some countries in SABRN	1000	Angola
	1000	Malawi
	400	Mozambique
1.1.4 Develop descriptors for candidate varieties	500	Malawi
	300	Mozambique
	500	Zambia
	500	Zimbabwe
1.1.5 Conduct DUS in applicable and present for release: 3 countries in SABRN	500	DRC
	1000	Malawi
	800	Mozambique
	500	Zimbabwe
1.1.6 produce breeder seed in countries that have released varieties	900	Angola
	1000	Malawi
	400	Mozambique
	1000	Swaziland
	800	Zambia
	800	Zimbabwe

Activity	Value	Country
1.2.1 On-farm evaluations using PVS	2250	Angola
	2800	DRC
	1500	Malawi
	2600	Mozambique
	3500	South Africa
	1500	Swaziland
	3000	Zambia
	1000	Zimbabwe
1.2.2 Develop descriptors for the new bean varieties	700	Zambia
	700	Zimbabwe
1.2.3 Produce breeders' seed for the new and old bean varieties	3000	DRC
	500	Zimbabwe
1.2.4 Rejuvinate BILFA, Drought and disease nurseries	1700	Angola
	3000	DRC
	1000	Malawi
	1700	Mozambique
	1500	Zimbabwe
1.2.8 Combine resistance and select for pyramid (ALS, CBB) in ZA and BSM (MW and ZW)	1500	Malawi
	7500	Zambia
1.2.10 Selection and testing of climbing beans adapted to mid-altitude (1200 -500 masl)	1500	Angola
	850	Mozambique
	2000	Zambia
	2000	Zimbabwe
1.3.1 Identify export market potential including enhancing competitiveness of beans in SABRN	500	Malawi
	500	Zimbabwe
1.3.2 Conduct a bean cross-border trade study across South TZ, South DRC and Zambia	3000	DRC
	1500	Zambia
1.4.2 Continue with backcrossing programme to improve commercial cultivars - Southern Africa	1000	Malawi
	4000	South Africa
1.4.3 Strengthen capacity for application of MAS - Bunda	4000	Malawi
1.4.6 Produce adequate seed for all breeding materials	1500	Malawi
	1500	Zambia
	1000	Zimbabwe
1.4.7 Production of foundation seed with partners	2000	DRC
	3700	Mozambique
	2000	Zambia
	1000	Zimbabwe

Activity	Value	Country
2.1.1 Validate effectiveness and farmers' acceptance and gender perceptions of promising ISFM and IPDM options with farmers	1850	Angola
	1000	Malawi
	500	Mozambique
	1000	Zambia
	1000	Zimbabwe
2.1.2 Disseminate and promote accepted options with partners for technologies in 10 all countries	1500	Malawi
	500	Mozambique
	1500	Swaziland
	2000	Zimbabwe
2.1.3 Perform cost-benefit tradeoffs analyses and adoption potential of these technologies	1000	Malawi
	1000	Zimbabwe
3.1.1 Organize, train and technically backstop community seed producers to bulk seeds	2000	DRC
	2500	Mozambique
	1000	Zimbabwe
3.1.2 Update number, type location and activities of service providers	250	Angola
	1000	DRC
	1000	Mozambique
	1000	Zimbabwe
3.2.3 Facilitate production of promotional and information publications (including publications for SABRN website), transilations in each network	950	Angola
	1000	DRC
	1000	Malawi
	1000	Mozambique
	1000	Swaziland
	1000	Zambia
	1000	Zimbabwe
5.5.2 Conduct participatory formulation and evaluation of a basket of diets for improved nutrition - using biofort products	2000	DRC
	2000	Malawi
	1500	Swaziland
	1000	Zambia
	1000	Zimbabwe

Activity	Value	Country
6.1.4. Conduct training workshops on nutrition assessment and linking nutrition support with agricultural extension	800	Swaziland
	1000	Zimbabwe
8.1.1 Inventory by year products (varietal and non-varietal), promotional materials	1750	Angola
	3500	Mozambique
TOTAL	**140050**	

HarvestPlus funded activities

Activity	Value	Country
1. Germplasm collection	4000	Malawi
	4000	Tanzania
	3000	Zimbabwe
2. Evaluation of fast trucks lines in various countries	2000	Angola
	2000	Lesotho
	2000	Malawi
	2000	DRC
	2000	Tanzania
	2000	Zambia
	2000	Zimbabwe
3. Breeding for high Fe combining with other biotic and abiotic stresses	2000	Malawi
	2000	South Africa
	2000	Tanzania
	2000	Zimbabwe
4. Supplies and small equipment: reagents, computer, printer	5000	SABRN
TOTAL	**40000**	

6.3 List of projects submitted, proposals, and concept notes prepared

6.3.1 At Headquarters

Title	Donor	Comments	Funding period	Total amount US
Extracting the best from a desert species: Mining tepary bean for drought tolerance	GCP	Concept note not selected for full proposal development	2008-2011	$889,350
Basal root architecture and drought tolerance in common bean	GCP	Concept note and full proposal approved	2008-2011	$ 345,000
An integrated experimental and modeling approach to optimize soil water use under limited water	GCP	Concept note not selected for full proposal development	2008-2011	$905,060
A cross-legume phenotyping effort to identify common traits for superior adaptation to drought	GCP	Concept note under review	2009-2011	$459,020
Improving tolerance to drought stress in crops	WUN	Seed grant under review	2009	$48,000

6.3.2 In Africa

Title	Donor	Comments	Funding period	Total amount US
Impact and development of Conservation Agriculture techniques in developing countries	European commission	Collaborators are: University of Applied Sciences Eberswalde, Germany; International Food Policy Research Institute (IFPRI), USA International, University of Ghana and Makerere University Participating CIAT technical team include: Enid Katungi and Roger Kirby	3 years	220,000 (CIAT's budget only)

Title	Donor	Comments	Funding period	Total amount US
Supporting Nutrition and health, Food security, Environmental Stresses and Market Challenges that contribute to improve livelihood and create income resource poor small holder families in Sub –Saharan Africa..	CIDA		2009-2013	7.8 million
Enhancing productivity, nutrition and incomes through improved marketable climbing bean and biofortified bean varieties	Government of Kenya	In review	2009-2011	$110,000
Improving Food and Nutrition Security, and Incomes of Smallholder Farmers in East and Central Africa through increased access to Markets and Technology Innovation	Belgium Development Cooperation (BADC)	Unsuccessful	2008-2011	$3,148,632
Climbing out from poverty: Realizing the benefits from high yield potential of Climbing beans for smallholder farmers in Africa	JIRCA	Presented to donor in Jan 2008		
Use of marker Assisted Selection in Developing Multiple Disease Resistant Bean Varieties in Malawi -	Kirk House Trust	Under review by donor (second round)	2009-12	150,000

7. STAFF LIST (INCLUDING % TIME ASSIGNMENT)

7.1 STAFF AT HEADQUARTERS

Stephen Beebe, PhD, Breeder, Geneticist, Project Manager (**70% SBA-1**, 30% SBA-6)
Matthew Blair, PhD, Germplasm Characterization Specialist, Bean Breeder (70% SBA-6, **30% SBA-1**)
Francisco Morales, PhD, Virologist (**30% SBA-1**, 50% PE-1)
Idupulapati Rao, PhD, Plant Nutritionist, Physiologist (**50% SBA-1**, 50% SBA-3)

7.2 STAFF IN AFRICA

Robin Buruchara, Ph.D., Plant Pathologist/CIAT Africa Coordinator (stationed in Kampala, Uganda **- 90% SBA-1**, 10% PA-2)
Rowland Chirwa, PhD, Plant Breeder/SABRN Coordinator (stationed in Lilongwe, Malawi - **100% SBA-1**)
Enid Katungi, PhD, Agricultural economist (stationed in Kampala, Uganda **- 100% SBA-1**)
Paul Kimani, PhD, Plant Breeder for ECABREN (University of Nairobi/CIAT, stationed in Nairobi, Kenya **- 75% SBA-1**)
Rachel Muthoni, BSc, MPA, Monitoring and Evaluation Specialist, (stationed in Kampala, Uganda **- 100% SBA-1**)
Jemimah Njuki, PhD, ERI Specialist, (stationed in Zimbabwe – **44% SBA-1**, 56% TSBF-1)
Martha Nyag'aya,, MSc, Nutrition (stationed in Kampala, Uganda – **90% SBA-1,** 10% TSBF-1)
Mukishi Pyndji, PhD, Plant Pathologist, ECABREN Coordinator (stationed in Arusha, Tanzania **- 100% SBA-1**)
Jean Claude Rubyogo, MSc, Seed System Specialist (stationed in Malawi – **100% SBA-1**)
Louise Sperling, PhD, Social Scientist, (stationed in Rome, Italy **- 80% SBA-1,** 20% SBA-6)

8. SUMMARY 2008 BUDGET PREPARED BY FINANCES: ACTUAL EXPENDITURES 2008

Outcome Line SBA-1: Beans

SOURCE	Bean Program			Total US$	(%)
	HQ + LAC	Africa	Biotech		
Unrestricted Core	622,284		120,901	743,185	7%
Restricted Core Japan			35,500	35,500	0%
Sub-total Core	**622,284**	**-**	**156,401**	**778,685**	**8%**
Restricted					
Special Projects	1,045,811	3,067,539	2,874,851	6,988,201	70%
Generation Challenge Program	35,450		254,592	290,042	3%
Harvest Plus	312,089		429,099	741,188	7%
Sub Total Restricted	**1,393,349**	**3,067,539**	**3,558,543**	**8,019,431**	**81%**
Direct Expenditures	**2,015,634**	**3,067,539**	**3,714,943**	**8,798,116**	**89%**
Non Research Cost	259,492	394,914	478,261	1,132,667	11%
Total Expenditures	**2,275,126**	**3,462,453**	**4,193,204**	**9,930,783**	**100%**

Product 1: Beans with improved micronutrient concentration that have a positive impact on human health

Activity 1.1 Developing more nutritious bean varieties

Highlights:

- More than 30 F_{3-5} small seeded Mesoamerican families were selected for high mineral concentration and some degree of drought resistance.
- Eighteen lines derived from interspecific crosses were coded as MIB (high mineral) lines, with levels of iron above those of the high iron check MIB 465. Some also have superior resistance to foliar pathogens.
- Over 200 pollinations were generated combining multiple sources of resistance to diseases and drought with high mineral (Fe and Zn) content in SABRN countries.
- Some good donor parent for drought resistance in common bean (SEA5, SEA15 and SER16) were also good parents for high Fe and Zn content.
- Several populations combining different market classes and disease or drought resistance, but also with high mineral (Fe and Zn) content have been generated, and some may have high Fe and or Zn content. Four bush and three climbing micronutrient dense bean varieties with high yield potential are pre-released for smallholder production in eastern Africa. This marks the first time biofortified mineral dense bean varieties are formally recommended for release following independent evaluations.
- Bioavailability of Fe in raw samples of fast track bean lines varies from 1.1% to 6.6%.
- Bioavailability of Zn in raw samples of fast track lines varies from 0.5 to 2.5%.
- Cooking enhances Fe and Zn bioavailability in beans by more than two fold.
- Freshly shelled beans have more bioavailable Fe and Zn compared with dry beans.

1.1.1 Development of new advanced lines from the program for the nutritional enhancement of Andean bush beans

Rationale: Iron deficiency anemia and other micronutrient deficiencies affect large numbers of people worldwide and biofortification is an approach to address this problem by breeding for higher micronutrient content in staple food crops. Legumes are a good source of iron and other essential micronutrients that are found only in low amounts in the cereals or root crops. Also beans and other grain legumes are usually consumed whole, thus conserving their nutritional content. An ongoing project has shown that bean seeds are variable in the amount of minerals (iron, zinc and other elements) that they contain and that these traits are likely to be inherited quantitatively. Over the past 4 years we have developed an initial set of Andean bush beans that have higher mineral content and red mottled seed type and named this set the NUA (Nutritional Andean) lines. These genotypes have now been widely distributed and a few of the advanced lines are near varietal release; their one drawback being a limited number of genetic parents used to develop the lines (predominantly CAL96 as recurrent parent and G14519 as high mineral parent). The objective of this research and varietal development program has been to create a new generation of NUA lines based on triple, double and multiple crosses using the original NUA lines as well as additional sources in various breeding combinations. This report summarizes the nutritional analysis of the F_6 derived lines which are currently in yield testing before shipment to partner countries in Eastern and Central Africa and further testing in Colombia. Most of the new genotypes aim to combine the high iron trait into red mottled background but we also derive some large red and cream mottled genotypes.

Materials and Methods:

Advanced lines were developed from the following donor parents for the high mineral trait: G14519, G23823E, G21242, NUA35, NUA56, BID29, BID115, through a series of backcrosses, simple crosses, triple crosses, double crosses and multiple crosses with the commercial parents: CAL96, CAL143, CAL144, PVA773, AND277 and AFR612 (all red mottled); as well as AFR298, RADICAL SAN GIL, RADICAL CERINZA, RED CANADIAN WONDER (G6592) (all large red seeded); SUG131 (cream mottled), KABLANKETI (G22454) (purple stippled), and DORE DE KIRUNDO (G21715) (large yellow). Some combinations contained the angular leaf spot resistance sources G5686 and MEX54 to complement those crosses with AND277 and CAL143 which also provide some resistance to the disease. After initial crosses and generation advance, single plant selections were made in the F_3 and F_6 generations. Seed multiplication for one generation was used to obtain seed for iron and zinc analysis which was carried out with atomic absorption spectroscopy (AAS) in CIAT analytical lab. Advanced lines were also selected for highly acceptable architecture, growth habit, yield potential and seed types.

Results and Discussion:

The selected genotypes were numbered consecutively beginning with the numbering of the previous NUA lines developed from the initial crosses for the biofortification program. A total of 490 advanced lines were developed with these listed as NUA101 through NUA591. The new NUA lines were organized based on pedigree and information on seed type was used to create separate nurseries for red mottled, large red and cream mottled genotypes for planting in Darién 2008B (Andic Dystrudept, pH 5.5, 1500 masl, average temperature 19°C, 500 mm during the crop cycle) season. Due to heavy rains throughout the season the planting was delayed until December which was a better period for planting into moist soils. In addition, a new plot was selected based on its soil type, which contained higher concentrations of iron and zinc compared with previous plots used.

A total of 76 pedigrees were represented by the 490 selected NUA lines and these were divided into backcrosses, triple, double and simple cross derived genotypes. Table 1 shows the summary of genotypes per pedigree, cross number, NUA codes and range of iron and zinc content (measured as parts per million or ppm) within each pedigree as well as the seed colors of the $F_{6:7}$ advanced lines derived from each cross.

For example, lines NUA101 to NUA265 (165 in total) were derived from backcrosses with AFR298, AFR612, RED CANADIAN WONDER (G6592), CAL144, PVA773, SUG131, DORE DE KIRUNDO (G21715) using the high mineral parents G14519 (Mesoamerican) and G21242 (Andean). Lines NUA266 to NUA411 (145 in total) were derived from triple crosses using a wider range of high iron parents (NUA35, NUA56, G23823E, BID29 and BID115) in the genetic background of commercial type parents AFR612, SUG131, PVA773, CAL96, CAL143 and CAL144 (these last two genotypes being sister lines with different yield and adaptation potential).

Lines NUA412 to NUA442 (31 lines in total) were derived from double crosses involving some of the same high iron parents (G23823E, BID29, BID115) and the large red seeded genotypes RADICAL SAN GIL, RADICAL CERINZA, AFR298, RED CANADIAN WONDER (G6592) as well as KABLANKETI (G22454). Finally, the lines NUA443 to NUA591 (143 in total), were derived from simple crosses between high iron genotypes NUA35, NUA56, G23823E, G21242, BID29 and BID115 with commercial red mottled and large red genotypes AFR298, AFR612, AND277, PVA773, KABLANKETI (G22454), G5686, MEX54, CAL96, CAL144, SUG131 and RADICAL CERINZA.

Table 1. Development of NUA lines from the program for the nutritional enhancement of Andean bush beans.

NUA number	Genotype	Total of lines	Iron range (ppm)	Zinc range (ppm)	Color type of beans
	Backcross				
101 - 140	AFR612 X (AFR612 X G14519)	40	73 - 41	31 - 18	Red mottled and red
141 - 161	CAL144 X (CAL144 X G14519)	21	84 - 53	49 - 23	Purple mottled, red mottled, red and purple
162 - 181	AFR612 X (AFR612 X G21242)	20	66 - 44	33 - 20	Red, red mottled and purple mottled
182 - 198	SUG131 X (SUG131 X G21242)	17	88 - 64	33 - 25	Cream mottled and red mottled
199 - 209	G21715 X (G21715 X G21242)	11	69 - 53	31 - 25	Yellow
210 - 220	AFR298 X (AFR298 X G14519)	11	66 - 45	37 - 27	Red
221 - 231	CAL144 X (CAL144 X G21242)	11	90 - 59	45 - 32	Red mottled, purple mottled and cream mottled
232 - 241	PVA773 X (PVA773 X G14519)	10	75 - 63	37 - 25	Red, red mottled
242 - 248	SUG131 X (G14519 X SUG131)	7	81 - 67	36 - 26	Red mottled and pink mottled
249- 250	SUG131 X (SUG131 X G14519)	2	65	25	Cream mottled and red mottled
251 - 255	AFR298 X (AFR298 X G21242)	5	64 - 52	28 - 25	Red
256 - 258	G6592 X (G14519 X G6592)	3	60 - 48	35 - 27	Red
258 - 260	G21715 X (G14519 X G21715)	2	61	25	Yellow
261 - 262	G22454 X (G14519 X G22454)	2	65 - 64	39 - 27	Purple mottled
263 - 264	G22454 X (G22454 X G21242)	2	56 - 53	25	Purple mottled
265	G22454 X (G22454 X G14519)	1	67	29	Purple mottled
	Triple Cross				
266 - 310	NUA35 X (AFR612 X BID115)	45	92 - 54	32 - 22	Purple mottled, red mottled and purple
311 - 328	NUA56 X (BID29 X SUG131)	18	75 - 48	30 - 24	Cream mottled, purple mottled, red, red mottled
329 - 340	NUA35 X (PVA773 X BID29)	12	77 - 63	30 - 25	Red, red mottled and purple mottled
341 - 351	NUA56 X (CAL143 X G23823E)	11	84 - 51	34 - 22	Purple mottled and red mottled
352 - 363	NUA35 X (AFR612 X G23823E)	12	81 - 67	30 - 25	Purple mottled and red mottled
364 - 371	NUA35 X (CAL96 X G23823E)	8	86 - 65	31 - 25	Red mottled and purple mottled
372 - 379	NUA56 X (AFR612 X BID115)	7	71 - 49	29 - 23	Red mottled and purple mottled
380 - 385	NUA35 X (BID29 X CAL144)	6	83 - 61	31 - 23	Purple mottled and red mottled
386 - 391	NUA56 X (PVA773 X BID29)	6	83 - 54	26 - 22	Red mottled
392 - 396	NUA56 X (AFR612 X G23823E)	5	86 - 62	31 - 22	Red and red mottled
397 - 400	NUA35 X (SUG131 X G23823E)	4	105 - 79	33 - 30	Purple mottled and red mottled
401 - 403	NUA35 X (CAL143 X G23823E)	3	98 - 62	27 - 24	Purple and red mottled
404 - 405	NUA35 X (CAL144 X G23823E)	2	84 - 83	29 - 27	Purple mottled
406 - 407	NUA56 X (CAL144 X G23823E)	2	80 - 60	24 - 21	Red mottled and purple mottled
408 - 409	NUA56 X (SUG131 X G23823E)	2	66	27 - 21	Purple mottled
410	NUA56 X (PVA773 X G23823E)	1	71	28	Purple mottled
411	NUA56 X (BID115 X PVA773)	1	72	28	Purple mottled

Table 1. cont'd.

NUA number	Genotype	Total of lines	Iron range (ppm)	Zinc range (ppm)	Color type of beans
	Double Cross				
412 - 417	(RAD.SANGIL X G23823E) X (BID115 X RAD.SANGIL)	6	74 - 48	35 - 24	Red
418 - 422	(RAD.CERINZA X G23823E)X(RAD.CERINZA X BID115)	5	73 - 61	31 - 27	Red
423 - 427	(AFR298 X G23823E) X (BID115 X AFR298)	5	81 - 64	39 - 31	Red
428 - 431	(RAD.SANGIL X G23823E) X (RAD.SANGIL X BID115)	4	78 - 69	32 - 26	Red
432 - 435	(AFR298 X G23823E) X (AFR298 X BID29)	4	63 - 54	33 - 25	Red
436 - 437	(G6592 X G23823E) X (G6592 X BID115)	2	79 - 75	30 - 28	Red
438 - 439	(G22454 X G23823E) X (BID29 X G22454)	2	76 - 60	31 - 28	Red
440 - 441	(AFR298 X G23823E) X (AFR298 X BID115)	2	71 - 62	37 - 33	Red
442	(G6592 X G23823E) X (BID115 X G6592)	1	75	32	Red
	Single Cross				
443 - 463	AFR612 X BID115	21	63 - 43	28 - 18	Red and red mottled
464 - 484	AND277 X NUA56	21	71 - 37	40 - 18	Purple mottled and purple
485 - 494	BID115 X G22454	10	68 - 48	37 - 27	Red
495 - 504	MEX54 X NUA56	10	70 - 47	41 - 23	Purple mottled
505 - 513	BID29 X CAL144	9	75 - 50	56 - 27	Purple mottled , red and red mottled
514 - 521	SUG131 X G23823E	8	90 - 65	44 - 37	Rosado mottled and cream mottled
522 - 528	RADICALCERINZA X BID115	7	60 - 44	34 - 28	Red
529 - 535	AFR298 X G21242	7	74 - 51	39 - 30	Red and cream mottled
536 - 542	AFR298 X BID29	6	85 - 56	32 - 27	Red
543 - 547	BID29 X SUG131	4	67 - 50	34 - 29	Red and cream mottled
548 - 555	BID115 X SUG131 or SUG131 X BID115	8	58 - 51	34 - 24	Red, cream mottled and red mottled
556 - 559	CAL143 X G23823E	4	75 - 52	27 - 22	White and red mottled
560 - 563	PVA773 X BID29	4	62 - 48	31 - 29	Red and red mottled
564 - 566	G5686 X NUA35	3	78 - 62	38 - 29	Purple mottled
567 - 568	RADICALCERINZA X G23823E	2	70 - 68	34 - 30	White
569 - 570	G6592 X G23823E	2	70 - 58	27 - 25	Red
571 - 572	AFR298 X G23823E	2	72 - 54	37 - 34	Purple
573 - 574	AFR298 X BID115	2	57 - 50	32 - 29	Red
575 - 576	BID29 X G21242	2	75 - 72	37	Red and purple mottled
577	BID29 X G22454	1	61	26	Purple mottled
578	BID29 X G23823E	1	66	33	Red
579	G21715 X G23823E	1	40	20	Cream mottled
580	G6592 X BID115	1	54	24	Red
581	CAL96 X G23823E	1	66	26	Purple mottled
582	PVA773 X BID29	1	49	28	Red mottled
583	CAL144 X G23823E	1	56	35	Purple mottled
584	AFR612 X G23823E	1	51	33	Cream
585	BID115 X AFR298	1	75	35	Pink mottled
586	AFR298 X G21242	1	0	0	Purple
587	RADICALSANGIL X G21242	1	46	14	Cream mottled
588	AFR298 X G21242	1	67	35	Purple
589	RADICALCERINZA X G21242	1	62	35	Cream mottled
590	AND277 X G23823E	1	79	28	Red
591	AND277 X NUA35	1	43	21	Red mottled

In terms of iron and zinc content the genotypes varied between 90 and 40 ppm iron and 35 to <10 ppm zinc in backcrosses, 98 to 43 ppm iron and 28 to <10 ppm zinc in triple crosses, 105 to 49 ppm iron and 34 to <10 ppm zinc in double crosses and 90 to 37 ppm iron and 36 to 10 ppm zinc in simple crosses. In each case some lower zinc advanced lines were kept because the corresponding iron levels were high or vice versa and for all the lines there are plans to confirm iron and zinc content either through NIRS or through a repetition of AAS analyses. These results show that there is large variability for iron and zinc content in the germplasm pool for Andean bush beans after improvement for mineral levels through the nutritional breeding. We were also pleased to find that high iron and zinc levels seem to be combining well with very commercial seed type and with better plant architecture and yield potential which was somewhat deficient in the first set of NUA lines.

In terms of seed colors, the commercial types could be classed into 145 large red, 127 dark red mottled, 125 light red mottled, 44 cream mottled, 19 purple speckled, 13 yellow, 7 pink mottled , 4 large white and 4 beige types. This set of NUA lines will provide a basis for additional breeding in each of these seed classes as the previous NUA lines were all of the red mottled seed class. Within the red mottled seed class, variability for seed brightness and tone will also be useful for ensuring that future combinations of breeding crosses have variability for this important commercial class which is preferred as a predominant type in Eastern and Southern Africa as well as parts of the Andean region.

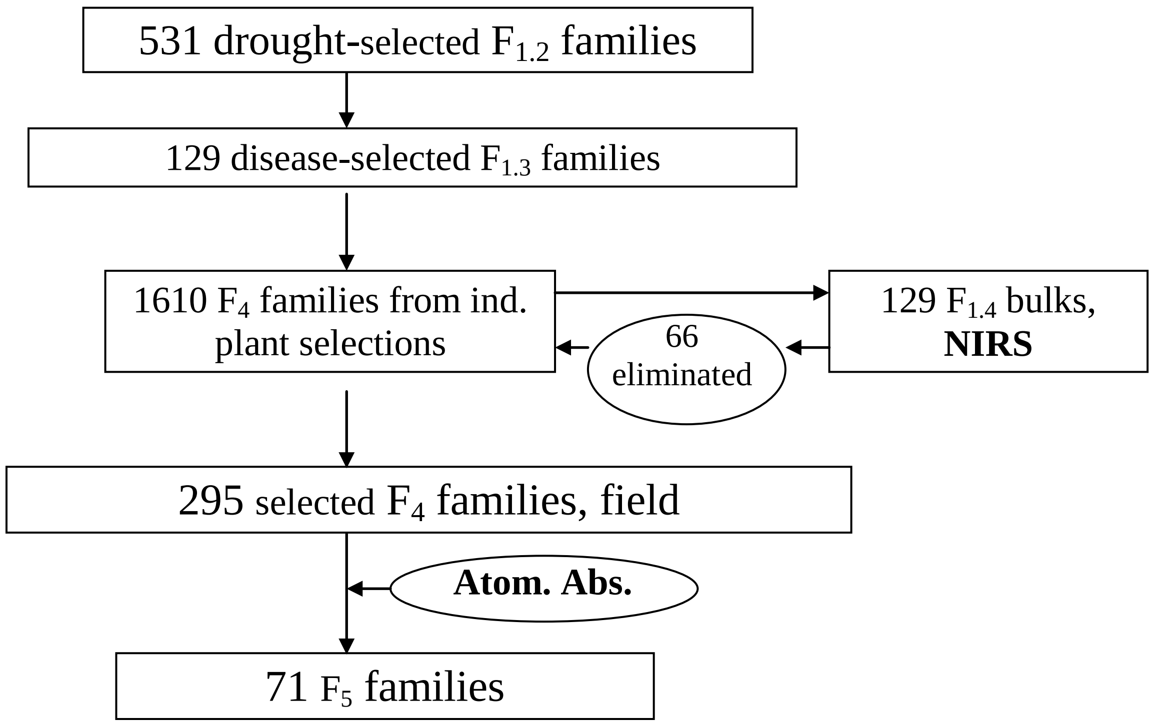
Future Plans: The present genotypes will be useful for studying mineral accumulation in large-seeded Andean beans and will be essential for further biofortification breeding efforts. They also may be useful for bioefficacy and bioavailability studies since they all show advantageous production characteristics which will allow them to be mass produced for nutritional promotion program. However, further testing to evaluate GxE interaction and to select the best NUA lines from this set are needed. Currently the yield potential of the genotypes is being tested at one mid-elevation site and seed multiplication is underway for shipment to the ISAR, INERA, ECABREN and SABRN breeding programs. It is expected that regional trials will be conducted with the best genotypes and that farmer preferences will be considered in the selection of the best candidate biofortified varieties prior to consumer testing for cooking time and culinary quality.

Contributors: M.W. Blair, F. Monserrate, C. Astudillo, A. Hoyos, Y. Viera, A. Hincapié (SBA-1)

1.1.2 Selection of Mesoamerican lines for high minerals in cycle 2 of recurrent selection in Colombia

Rationale: Improvement of the nutritional value of common beans has become one of the central themes of the CIAT program, both in Latin America and Africa. The CIAT Bean program continues to be fully committed to developing agronomically acceptable bean lines with varietal potential and with higher levels of iron and zinc. In the case of Mesoamerican beans, our goal is to produce lines that are also drought resistant to make them attractive to farmers.

Materials and Methods: F_2 populations of double (4 parent) crosses combining iron, drought tolerance and disease resistance were evaluated for drought tolerance in July 2007. 531 selected $F_{1.2}$ populations were subsequently planted in Popayán in October 2007 for inoculation with the anthracnose pathogen. 1610 individual plants were harvested from 129 populations with superior performance, and planted in Quilichao for evaluation of ALS resistance. Bulk remnant seed of the individual selections was evaluated with NIRS, permitting the elimination of 66 of the 129 populations based on low iron. Of the remaining F_4 families in Quilichao, 295 were selected based on field performance and evaluated for iron and zinc by atomic absorption, permitting the selection of 71 $F_{3.5}$ families for evaluation in the 2008 drought nursery. This selection scheme is outlined in Figure 1.



Correlation (NIRS F_4; A.A. F_5) = 0.49

Figure 1. Combining field selection, NIRS and Atomic Absorption

The 71 selected families were planted in 3 different lattice designs. 867 individual plant selections were taken within the plots of the most promising families based on visual evaluation of productivity for planting plant-to-row, and the grains of these were weighed and added to the plot yield. Minerals were analyzed by atomic absorption of bulked seed of selections, and by NIRS of individual plants, and both data were used in the selection of F_6 families.

Results and Discussion: The correlation between iron estimated by NIRS in $F_{3.4}$ and atomic absorption in $F_{3.5}$ was 0.49. While only moderate, this in fact is quite good considering that, 1) the population was severely truncated between the F_4 and F_5 generations, reducing the genetic variability on which the correlation was calculated; 2) the F_4 generation represented a bulk of selected plants, and thus the value of NIRS reflects an average of the variability within the family as compared to the F_5 families; 3) the environments of the F_4 and F_5 generations were very different.

Drought was intermittent in 2008 and the crop suffered moderate drought stress. Nonetheless several of the selected lines out-produced the commercial check, Tio Canela which averaged 1781 kg ha^{-1} over the three trials (Table 2). Tio Canela is well adapted to intermittent drought, and thus a yield which is superior to that of Tio Canela is quite promising.

Table 2. Families selected for high iron, drought tolerance and resistance to foliar pathogens

Cross code	Pedigree	# fam. Sel.	COL	Fe, $F_{3.5}$ bulk	Fe, F_{3-6} bulk, Drt	Range in Fe, F_6 sel. (NIRS)	Zn, F_{3-5} bulk	Zn, F_{3-6} bulk Drt	kg ha^{-1} Drt	ANT	ALS	bgm-1	W12
16168-017	(NCB 226xRCB 591)F1 X (SXB 597xMIB 497)F1/-MC-4P-MQ-1C	9	Lt. rd	71	66	57-69	32	29	2300	1/4	4		
16168-017	(NCB 226xRCB 591)F1 X (SXB 597xMIB 497)F1/-MC-5P-MQ-1C	3	rd	66	70	58-65	33	29	2089	1/4	4		
16181-017	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-23P-MQ-1C	2	cr	71	67	67-68	30	28	2268	2	3	+	+
16181-019	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-20P-MQ-1C	3	cr str	68	63	67-77	31	28	1997	1/4	6	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-2P-MQ-1C	1	cr	78	72	71	31	27	2080	1	5	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-7P-MQ-1C	4	cr str	93	72	64-79	34	28	1681	1	5	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-11P-MQ-1C	3	cr	87	71	69-74	34	29	2351	1	5	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-12P-MQ-1C	8	cr	86	73	68-88	31	29	2329	1	4	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-13P-MQ-1C	7	cr str	75	62	68-92	32	29	1678	1	5	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-17P-MQ-1C	4	cr	76	65	66-80	33	29	2281	1	3	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-19P-MQ-1C	7	cr str	86	76	70-84	31	30	1743	1	5	+	+
16181-020	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-21P-MQ-1C	6	cr	76	62	67-78	31	26	2166	1	5	+	+
16181-025	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-2P-MQ-1C	1	cr str	79	69	68	40	27	1940	2/4	6	-	+
16181-025	(SXB 405xSEN 37)F1 X (SMB 3xMIB 602)F1/-MC-20P-MQ-1C	2	cr	85	67	72-82	35	28	1977	2/4	6	-	+
16187-021	(SXB 403xSEN 53)F1 X (SMB 6xMIB 601)F1/-MC-2P-MQ-1C	8	bl	97	63	63-84	40	35	2092	_1/5	6		
16188-006	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-12P-MQ-1C	1	bl	78	53	75	35	28	2456	1	5		
16188-008	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-14P-MQ-1C	8	bl	75	58	68-80	33	27	2389	1/3	3		
16188-009	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-4P-MQ-1C	2	bl	73	66	68-81	32	26	2099	2	1		
16188-009	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-11P-MQ-1C	2	bl	79	56	73-81	32	26	2040	2	1		
16188-025	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-1P-MQ-1C	1	bl	69	79	67	35	28	2176	5	5		
16188-025	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-4P-MQ-1C	11	bl	73	66	71-100	31	27	2268	5	5		
16188-025	(SEN 52xSEN 67)F1 X (MIB 487xMIB 601)F1/-MC-9P-MQ-1C	14	bl	100	78	69-88	36	33	1965	5	6		
16198-044	(SER 119xSEN 46)F1 X (MIB 499xMIB 602)F1/-MC-1P-MQ-1C	9	bl	90	83	68-90	36	28	1453	1	3		
16204-010	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-4P-MQ-1C	5	cr str	84	64	71-79	38	27	1660	1/5	4		
16204-010	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-5P-MQ-1C	4	cr str	86	54	73-79	41	26	2056	1/5	2		

Table 2. cont'd.

Cross code	Pedigree	# fam. Sel.	COL	Fe, $F_{3.5}$ bulk	Fe, F_{3-6} bulk, Drt	Range in Fe, F_6 sel. (NIRS)	Zn, F_{3-5} bulk	Zn, F_{3-6} bulk Drt	kg ha^{-1} Drt	ANT	ALS	bgm-1	W12
16204-010	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-7P-MQ-1C	14	pk sp	72	61	71-101	35	28	2117	1/5	3		
16204-010	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-12P-MQ-1C	6	cr str	73	73	68-90	34	30	1519	1/5	6		
16204-010	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-15P-MQ-1C	6	cr str	77	68	76-89	33	32	1565	1/5	5		
16204-010	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-16P-MQ-1C	1	cr str	74	69	61	32	26	2351	1/5	3		
16204-016	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-2P-MQ-1C	15	rd	69	69	68-87	24	28	2102	1/5	6		
16204-016	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-14P-MQ-1C	5	rd	71	60	75-92	28	27	1962	1/5	6		
16204-016	(SXB 407xSER 119)F1 X (MIB 499xMIB 602)F1/-MC-16P-MQ-1C	9	rd	94	70	69-80	29	27	2052	1/5	6		
16218-009	(SXB 415xAQB 608)F1 X (SMB 3xMIB 499)F1/-MC-8P-MQ-1C	7	cr str	71	67	60-73	36	27	1867	1/3	5		
16218-009	(SXB 415xAQB 608)F1 X (SMB 3xMIB 499)F1/-MC-13P-MQ-1C	1	cr str	85	71	80	38	29	1715	1/3	3		
16246-020	(SER 76xRCB 589)F1 X (MIB 499xMIB 602)F1/-MC-8P-MQ-1C	1	bl	74	71	69	36	27	1960	1	6	+	-
16291-002	(SER 42xRCB 593)F1 X (MIB 487xMIB 601)F1/-MC-4P-MQ-1C	6	bl	74	61	70-82	40	27	2363	2	5		
16291-002	(SER 42xRCB 593)F1 X (MIB 487xMIB 601)F1/-MC-7P-MQ-1C	2	rd	74	52	71	32	23	2409	2	1		
16291-036	(SER 42xRCB 593)F1 X (MIB 487xMIB 601)F1/-MC-11P-MQ-1C	3	bl	76	60	70-82	39	31	1792	1	3		
	DOR 500			55	59	53	36	28					
	CAL 96			42	60	51	25	22					
	MIB 465			70	86	90	50	39					

COL=Color; Lt rd=light red; rd=red; bl=black; cr=cream; cr str=cream striped; Drt= drought; ANT=anthracnose (1-9 scale); ALS=angular leaf spot (1-9 scale); bgm-1 and W12=QTL for resistance to BGMV.

Among the 867 F_5 individual selections made within the 71 F_{3-5} families under evaluation in drought, a total of 201 F_6 lines were maintained, derived from 38 of the $F_{3.5}$ families (Table 2). Both NIRS and atomic absorption evaluation suggest that some of these may be drawing close to the level of iron in the high iron check, MIB 465. Most have acceptable levels of resistance to anthracnose, several are resistant or intermediate to ALS, and a number of them are segregating genes for resistance to BGYMV (pending evaluation). Very few have acceptable red grain color, but a number are black seeded, and others are cream or cream-striped (carioca) type.

It must be noted that the values of iron represented here tend to be lower than the real values. Accuracy of the atomic absorption and NIRS values is monitored using uniform, universal checks of bean flour (DOR 500 and MIB 465) in each evaluation. These samples were evaluated by ICP in Adelaide and in Cornell, giving respective values of 64 and 102 ppm iron. Our values of both NIRS and atomic absorption tend to be about 16% below these values.

Crosses from cycle 2 of the recurrent selection scheme were also sent to Central America in 2007. These have been selected on site. We have analyzed grain of 96 selections from Zamorano, Honduras; we are awaiting the release of some 97 samples from Nicaragua from Colombian quarantine; and we are expecting the shipment of 54 samples from El Salvador and 99 from Guatemala.

A second set of crosses within cycle 2 of recurrent selection were planted as $F_{1.2}$ populations in drought in July, 2008, and in Popayán as $F_{1.3}$ populations for anthracnose evaluation. These are undergoing the same selection process described above, with the possible modification of NIRS evaluation of individual plants, if this procedure proves to be effective.

Collaborators: S. Beebe, C. Cajiao, M. Grajales, M.L. Cortés, A.F. Guerrero

1.1.3 Development of new sources for high iron: Selection among interspecific families

Rationale: In previous reports we have informed about the utilization of *Phaseolus polyanthus* and *Phaseolus coccineus* as sources of high iron to improve common bean. In some trials the former species has presented as much as 127 ppm in iron, or perhaps 20 ppm higher than that found in common bean. Since these two species cross readily with *P. vulgaris*, they were used to improve the levels of minerals in common bean. These species are also resistant to several fungal pathogens of bean, and although often used as sources of these traits to improve common bean, this is the first attempt to use them as a source of nutritional traits.

Materials and Methods: High mineral accessions G35575 (*P. polyanthus*) and G35999 (*P. coccineus*) were crossed to three common bean genotypes: FEB 226 (carioca), CAL 96 (calima type), and G2333 (Mesoamerican climber). Only crosses of FEB 226 with G35575 have proved to be promising and are reported here. Populations were selected from the F_2 to the F_4 generation using pedigree selection. In each generation individual plant selections were made and seed was sampled from each individual plant within a family for evaluation as a bulk for mineral concentration. All mineral concentrations were estimated by atomic absorption in CIAT's Analytical Services laboratory, using both uniform checks in the field, and laboratory checks of known mineral concentration. In the course of 2008 these families reached the F_5 generation.

Results and Discussion: Over several seasons some families and lines have maintained an advantage of 40 ppm over the low iron checks (Table 3). For example, MIB 755 presented levels of iron of 85, 72 and 80 ppm versus DOR 500 with 45, 39, and 43 ppm. Furthermore in the Popayán environment the iron values tend to be compressed such that the range in values is narrower, and the high iron check, MIB 465 (which normally presents 85-90 ppm iron) expresses only 65-75 ppm. The interspecific lines have presented 10-15 ppm more than the high iron check! It is fully possible that if these genes can be introduced into other genetic backgrounds that give adaptation to other environments, this range of iron expression could be even wider. These lines could well represent levels of iron that meet the goal of 95-100 ppm. In two preliminary tests in Palmira, some of the lines continued to express high iron, as high as 100 ppm (data not shown). However, data from Palmira must be taken with caution in this case, as the lines tend not to adapt well in Palmira (as expected). Under higher temperatures most tend to be late maturing and with poor pod load, which may augment their iron concentration in this environment.

Several lines also express levels of zinc of 45-56 ppm in Popayán, which are above that of the high mineral check, MIB 465 with 38-36 ppm (Table 3). This is also very exciting, considering that the levels of zinc in the newest lines from intraspecific crosses have improved modestly at best (Table 2 Section 1.1.2).

Table 3. Selected interspecific families with high iron and zinc, derived from crosses of common bean line FEB 226 and *P. polyanthus*.

MIB	Cross code	Identification	Fe, ppm, $F_{4\text{-}6}$	Fe, ppm $F_{4.5}$	Fe, ppm $F_{3\text{-}4}$	Fe, ppm $F_{2\text{-}3}$	Zn, ppm $F_{4\text{-}6}$	Zn, ppm $F_{4\text{-}5}$	Zn, ppm $F_{3\text{-}4}$	Zn, ppm $F_{2\text{-}3}$
748	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-1P-3P-8P-MP	62	60	81	63	40	36	43	31
749	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-1P-2P-MP	**74**	72	85	63	**50**	43	43	31
750	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-1P-3P-MP	**74**	72	85	63	**55**	43	43	31
751	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-1P-4P-MP	**82**	72	85	63	**49**	43	43	31
752	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-1P-7P-MP	**81**	72	85	63	**48**	43	43	31
753	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-18P-2P-MP	**81**	72	85	63	41	39	43	31
754	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-18P-3P-MP	**79**	72	85	63	41	39	43	31
755	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-18P-4P-MP	**80**	72	85	63	44	39	43	31
756	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-12P-4P-1P-MP	68	55	86	63	43	34	50	31
757	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-12P-4P-8P-MP	63	55	86	63	40	34	50	31
758	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-12P-4P-10P-MP	65	55	86	63	41	34	50	31
759	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-12P-4P-12P-MP	**70**	55	86	63	43	34	50	31
760	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-12P-4P-13P-MP	**75**	55	86	63	**47**	34	50	31
761	FEIN 15545-19	FEB 226 X (FEB 226xG 35575-2P)F1/-13P-2P-11P-MP	**71**	58	80	63	**45**	33	45	31
762	FEIN 15545-18	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-2P-1P-MP	68	70	97	81	**56**	44	56	40
763	FEIN 15545-18	FEB 226 X (FEB 226xG 35575-2P)F1/-10P-2P-5P-MP	**80**	70	97	81	**52**	44	56	40
764	FEIN 15546- 5	FEB 226 X (FEB 226xG 35575-5P)F1/-3P-8P-6P-MP	63	68	71	71	**52**	42	41	43
765	FEIN 15546- 5	FEB 226 X (FEB 226xG 35575-5P)F1/-3P-8P-7P-MP	**71**	68	71	71	**49**	42	41	43
	Field checks	CAL 96	39	39	.	42	31	25	.	28
		DOR 500	43	39	45	37	33	29	31	31
		FEB 226	48	45	.	44	33	29	.	31
		MIB 465	63	75	63	63	46	38	43	42
		MIB 466	64	63	.	55	37	31	.	37
	Lab checks	DOR 500, universal ch.*	59	59	59		25	22	25	
		MIB 465, universal ch.*	93	98	71		37	35	40	

* Universal checks DOR 500 and MIB 465 have true iron values of 64 and 102 ppm respectively, as determined by ICP in Waite Laboratory, Adelaide, AU, and in Cornell University.

Most lines have a carioca grain type, and although not yet ready for deployment in the warm tropics where carioca is used in Brazil, they could have utility in areas of highland Africa where BCMNV is less prevalent. They have shown excellent yield potential in Popayán, as well as improved disease resistance compared to the common bean parent, FEB 226 (Figure 2).

Collaborators: S. Beebe, C. Cajiao, M. Grajales, M.L. Cortés

Figure 2. Common bean line FEB 226 (left) compared with MIB 755 (right), a high iron interspecific progeny of FEB 226 and *P. polyanthus*.

1.1.4 Breeding of Andean beans to create lines with higher mineral content and superior agronomic traits in southern Africa

Rationale: Following on the breeders' workshop which was held in Kampala, Uganda 2005, several countries within SABRN started breeding activities to improve Andean beans for higher mineral content and superior agronomic traits. During this reporting period, various countries continued to generate crosses combining multiple sources of resistance to diseases, high mineral content and drought.

Materials and Methods: Crosses were generated by various NARS programs (South Africa, Tanzania, Zambia and Zimbabwe) and the regional breeding program in Malawi. The female parental sources representing the major market classes, as well as the donor parents for resistance to targeted diseases and for high Fe and Zn content were identified during the breeders training workshop in Kampala.

Results and Discussion: In Tanzania, they noted that the first set of high micronutrient density NUA and other lines were not well adapted due to susceptibility to diseases, particularly ALS. The NUA lines were also low yielding compared to the standard bean varieties in southern highlands of Tanzania. To improve the Fe and Zn content in bean varieties, a crossing program was initiated. Over 50 pollinations were made to build up disease resistance and to get better grain type. The progenies were grown as bulk population at F_3 generation and F_4 seed has been harvested. Selected lines under disease pressure at F_4

generation were crossed to NUA 45 and NUA 56 during the mid-August 2008 planting. In addition 40 pollinations were made between varieties Kirundo and Uyole 04 and also between Kirundo and OR-BR – a local breeding line which is resistant to several diseases at Uyole Agricultural Research Institute. The progenies were at F_3 generation, and sufficient seed had been harvested to plant F_4 population, which will be evaluated under disease pressure. The selected best progenies will be crossed to NUA45 and NUA56 for high micronutrient content.

In Zimbabwe, over 25 new crosses were initiated where they used three NUA lines as male donor parents for high mineral content - NUA45, NUA59 and NUA35 to improve the following female parents: Red Canadian Wonder, DRK68, CIM9314-17, CAL143, VTTT923/10-3, MG38, AND897, DRK134, RAA34, purple, brown and G17722 – representing the red kidney, red mottled, sugar, purple and brown market classes. Purple and brown were local landraces with good attributes (resistance to drought, good pod load, good market class). The crosses also included parents with multiple traits for disease resistance. The progenies from the earlier crosses were at F_4 generation.

In Zambia, the breeding program had generated over 40 crosses combining attributes from various landrace varieties (Kablanketi, Solowezi Rose, Pembela, Lusaka Yellow) which had good market classes and some released varieties which had good disease resistance (Lyambayi and Lukupa) with high mineral content from AND620, NUA45 and NUA59.

In Malawi the regional breeding program made 80 new 2-way crosses, resulting in 320 seeds at F_1 generation, combining preferred market classes and disease resistance, using MEX54 and AND277 as sources of angular leaf spot (ALS) resistance and XAN159 or VAX6 or RMX27 as sources of resistance to common bacterial blight (CBB). These will be grown in a screen house, and will be crossed either as F_1xF_1 to combine more than one resistance genes for diseases or to AND620 and NUA56 as sources of high Fe and Zn. In addition there were 88 families in $F_{1:2}$ generation and 606 $F_{2:3}$ generation originating from 3-way crosses combining good parental lines for ALS (MEX54, CAL143) or CBB (XAN159, VAX6 or RMX27) and high Fe & Zn (NUA56 and AND620) were planted in single row plots 4 m long (41 plants) at Chitedze and Bembeke to evaluate them for CBB and ALS respectively. These populations were in various market classes: Calima (CAL113), Khaki (Nasaka) and purple (Kablanketi). Both sites were hit by drought, because the rains cut off early this year, and disease pressure, especially for CBB at Chitedze was not significant, but more importantly, grain harvest was very limited, such that selection was not justified. Remnant seed of these families has been grown at Bwanje, this June 2008 under irrigation to generate F_3 and F_4 families, which will be further evaluated during the coming rainy season. Grain samples from select plants at F_4 generation will be evaluated for high Fe and Zn.

In South Africa, 57 new 3-way crosses were made, realizing 225 seeds at F_1 generation, combining preferred bean market class, disease resistance and high micronutrient content. The focus was on improving the nutritional value of red speckled sugar (RSS) with resistance to rust, angular leaf spot (ALS) and common bacterial blight (CBB) and halo blight (HB) and using AND620 and NUA56 as donor parents for high Fe and Zn content. Apart from the new crosses, some countries had advanced generations of segregating populations from the earlier crosses, which combined parental sources for various diseases and high mineral content. The $F_{1:2}$ segregating populations, combining CBB resistance and high Fe and Zn content, as well as those combining ALS, rust x Fe and Zn progenies were evaluated for disease resistance in the field during summer 2008. For CBB resistance, 178 single plant progeny rows ($F_{2:3}$ generation) were planted in June 2008 at Makhatini Research Station, KwaZulu-Natal and similarly under inoculation inoculated. CBB resistant single plants were selected and 315 single row plots ($F_{3:4}$), were planted at the ARC-GCI in December 2008. For ALS and rust resistance 330 single plant progeny rows ($F_{2:3}$ generation) with AND620 and NUA56 as donor parental lines and progeny rows from bulked F_2 populations were planted during June 2008 at Makhatini Research Station, KwaZulu-

Natal. After further single plant selection, 548 ($F_{3:4}$), were selected and harvested and planted in single progeny rows at Cedara Research Station during in December 2008.

In addition, there were some plants which were selected from progeny rows with SEA5, SEA15 and SER16 as donor parents for drought as well as high Fe and Zn content. These together with the redundant plants from progeny rows of AND620 and NUA56 as donor parents were harvested in bulk at Cedara in 2008 and retained for Fe and Zn analyses. Forty one (41) samples of grain each consisting of 40 seeds (± 10-15g each), preferably in RSS and cranberry types were selected for analyses at the ARC-soil, climate and Water Institute (ISCW), Pretoria, South Africa. In addition 19 samples of parental lines and cultivars were included as checks. Results from the analyses showed that some of the progenies like P743, P748, P750, P751 and P780 had higher Fe and Zn content than one or both of their parents (Table 4). It was also worth noting that some bred varieties like OPS-RS4 from South Africa showed good levels of Fe content. In addition, lines used in crosses as good sources of resistance to drought, SEA15, SER16 and SEA5 also showed to have good levels of Fe and Zn, indicating that we might have more sources of parents for high Fe and Zn, and that some parents are both good sources for drought as well as Fe and Zn

Table 4. Fe and Zn content data from selected progeny and parental lines used in generating the breeding for high Fe and Zn content.

Identity	**Line/Cross**	**Pedigree**	**Nutrient content (ppm)**	
			Fe	**Zn**
P743	PC3834	PC 3674/AND620	154	44
P748	PC3840	PC 3677/AND620	149	38
P780	PC3870	PC3725/NUA56	117	34
P750	PC3841	PC 3677/NUA56	114	43
P751	PC3847	PC 3681/AND620	113	39
P744	PC3834	PC 3674/AND620	112	45
P747	PC3840	PC 3677/AND620	108	34
P764	PC3853	PC3684/NUA56	108	36
P749	PC3841	PC 3677/NUA56	104	33
P759	PC3852	PC3684/AND620	102	37
P768	PC3853	PC3684/NUA56	102	36
P763	PC3853	PC3684/NUA56	100	29
P772	PC 3864	PC3714/AND620	100	41
P760	PC3852	PC3684/AND620	99	40
P767	PC3853	PC3684/NUA56	99	34
P757	PC3848	PC 3681/NUA56	96	33
P771	PC 3864	PC3714/AND620	96	37
P746	PC3835	PC 3674/NUA56	95	32
P761	PC3853	PC3684/NUA56	95	31
P745	PC3835	PC 3674/NUA56	94	41
P758	PC3848	PC 3681/NUA56	94	36
P756	PC3848	PC 3681/NUA56	93	37
P769	PC3860	PC3711/SEA56	93	34
P753	PC3847	PC 3681/AND620	92	36
P755	PC3848	PC 3681/NUA56	92	31
P762	PC3853	PC3684/NUA56	92	35
P766	PC3853	PC3684/NUA56	92	38
P773	PC3865	PC3714/NUA56	92	37
P765	PC3853	PC3684/NUA56	91	32
P752	PC3847	PC 3681/AND620	90	35
P782	PC3870	PC3725/NUA56	90	32

Table 4. cont'd.

Identity	Line/Cross	Pedigree	Nutrient content (ppm)	
			Fe	Zn
P754	PC3847	PC 3681/AND620	88	38
P770	PC3861	PC3711/SEA5	88	36
P778	PC3870	PC3725/NUA56	88	30
P781	PC3870	PC3725/NUA56	88	31
P774	PC3865	PC3714/NUA56	87	36
P775	PC3869	PC3725/AND620	87	30
P777	PC3870	PC3725/NUA56	82	34
P776	PC3869	PC3725/AND620	81	36
P779	PC3870	PC3725/NUA56	79	33
P783	PC3870	PC3725/NUA56	76	28
P793	SEA 5		190	42
P792	SER 16		127	38
P789	OPS-RS4		125	35
P791	SEA 15		116	40
P799	PC3834		116	37
P784	NUA 56		106	31
P787	SEDERBERG		101	35
P790	PAN 116		100	31
P794	PC 3725		99	30
P796	PC 3681		96	31
P797	PC 2526-BC2 (14)		96	37
P802	RS6		93	38
P788	KRANSKOP-HR1		91	35
P800	KRANSKOP		91	36
P795	PC3714		89	27
P785	AND 620		88	33
P786	JENNY		84	35
P798	PC3677		82	37
P801	RS5		82	32

Contributor: R. Chirwa

Collaborators: A. Liebenberg, M. Liebenberg, D. Fourie, J. Bokosi, C. Madata, G. Makunde, K. Muimui, S. Beebe, M. Blair, R. Buruchara, P. Kimani

1.1.5 Breeding micronutrient dense bean varieties in eastern Africa

Introduction. Development and utilization of biofortified varieties is regarded as probably the most effective and sustainable and potentially long-lasting strategy for reducing micronutrient deficiencies in Africa. Micronutrient malnutrition is now recognized as one of the most serious health challenges facing vast sectors of Africa's population particularly resource-poor women and children (Kimani et al., 2001). Major deficiencies include iron, zinc, vitamins and protein. Micronutrient deficiency is often referred as 'hidden hunger' because the problem does not show any easily recognizable symptoms in the early stages, until it is almost too late, when considerable, and often irreversible damage has occurred. Prevalence of iron deficiency anaemia (IDA) varies from 8% in Ethiopia, 67% in Tanzania, to 69% in Burundi. The main cause of these deficiencies is a diet rich in energy but poor in proteins, minerals and vitamins. The problem is further aggravated by widespread poverty, which makes it difficulty for the vast majority to access the more expensive animal based products, which are rich in vitamins and minerals. Limited knowledge on the nutritional value of locally available foodstuffs and changing eating habits that regard traditional vegetables and other non-staples as 'old-fashioned' have further worsened the problem. The preferred foods include cereal-based products (sifted maize meal, milled rice), white potatoes and cassava that are generally low in micronutrients.

A three-pronged approach has been followed in alleviating the micronutrient deficiency problem in Africa. These are: supplementation of vulnerable groups with micronutrients, fortification of common processed foods, and dietary improvement. Mineral supplementation is effective for easy-to-reach vulnerable groups with access to medical facilities. In East and Central Africa, this constitutes a very small group. It requires a large capital input, an elaborate and costly distribution network and patience compliance. It has to be carried out on a regular basis. This approach often leaves out those hard-to-reach or practically unreachable at-risk groups as well as other household and community members not targeted to receive any kind of supplementation. In Africa, the latter group constitutes the majority who are located in rural communities with limited access to medical facilities and too ill from the effects of the deficiency. Fortification of common foods has had a limited degree of success in Africa because of the under-developed food industry and lack of effective legislation. For example, at present food fortification programs are operational only in two of the ten ASARECA member countries in East and Central Africa: Kenya (vitamin A and iron in wheat flour, maize flour, millet porridge, margarine and cooking oil) and Uganda (iron in wheat flour). The number is equally small in southern Africa. Food fortification is effective for small affluent communities mostly in urban areas and households with a capacity to purchase fortified foods on a regular basis. This again leaves out the majority of urban poor and rural communities. Dietary improvement is probably the most effective and sustainable strategy for reducing micronutrient deficiencies in Africa. This approach aims to increase dietary availability, regular access and consumption of mineral-rich foods in at - risk and micronutrient-deficient groups of populations. It involves development and promoting enhanced consumption of culturally acceptable, mineral rich grains, vegetables and root crops.

Program Objectives: A regional program led by PABRA, and based at the University of Nairobi and the Malawi National Bean program in partnership with CIAT and HarvestPlus was initiated in 2001. The objectives of this program were to: (i) Characterize the variation of grain iron and zinc concentration in east, central and southern Africa, (ii) identify potential parents for further breeding work, and iii) determine whether there are regions with high diversity for this trait and complement existing collection at Genetic Resources Unit at CIAT, Colombia, iv) identify lines which could be fast-tracked as mineral dense lines for cultivation by farmers in regions with severe Fe and Zn malnutrition, v) assess the cooking, bioavailability of Fe and Zn and other organoleptic characteristics of promising mineral dense lines.

Variety development. Major steps in development of common bean varieties rich in micronutrients has involved collection and screening of varieties, landraces, germplasm accessions and advanced lines for micronutrients, participatory evaluation of promising lines for adaptability and agronomic traits in observation and preliminary on-farm and on-station trials, advancement and further characterization of selected lines in advanced and multi-location yield trials to generate data required for formal release, and production of breeder seed to facilitate production and dissemination of commercial seed to end users. Genotypes with high concentration of micronutrient but lacking in agronomic traits and susceptible to major diseases entered hybridization programs to generate segregating populations and select for lines combining mineral density with resistance to biotic and abiotic stress factors, marketable grain types and high yield potential. We previously highlighted the regional strategy adopted in the development of micronutrient rich bean varieties (CIAT, 2007). This report highlights key milestones reached by the regional program towards the development and release of micronutrient dense varieties for smallholder farmers in eastern, central and west Africa between 2003 and 2008.

Materials and Methods: Bean germplasm was collected in nine countries in east and central Africa. Collections included landraces, varieties, introductions, germplasm accessions and breeding lines held by national bean programs and gene banks. A germplasm collection, characterization and conservation protocol was developed and distributed to bean programs in east, central and southern Africa. Samples were analyzed at the University of Nairobi (Kenya), and subsequently at CIAT (Colombia), Cornell University (USA), University of Copenhagen (Denmark) and Sokoine University (Tanzania) to facilitate cross-lab comparison (CIAT, 2001, 2002, 2003 and 2004). Thirty-eight fast track lines were identified and distributed for regional evaluation across agro-ecological zones in more than 15 countries in east, central and southern Africa, and later in West Africa (CIAT, 2004, 2007). Fast track lines were also evaluated for anti-nutritional factors (tannins and phytates), cooking time, mineral retention and other organoleptic characteristics (CIAT, 2005, 2006, 2007). Genotypes with high micronutrient concentration but lacking in preferred agronomic traits and susceptible to major diseases were entered in hybridization program at Kabete to generate segregating populations and select for lines combining mineral density with resistance to biotic and abiotic stress factors, marketable grain types and high yield potential. Mineral analyses were performed used ashing and wet digestion techniques (Zarcinas et al., 1983). Normal agronomic practices were followed in field trials. Data was analyzed using Genstat and/or SAS statistical software.

Results and Discussion:

Germplasm screening. Although PABRA partners had a target of 2000 accessions, more than 2853 germplasm accessions were collected in nine countries in east and central Africa in the last five years (Table 5). They included landraces, old varieties and some breeding lines. Mineral analyses showed that there was considerable genetic variation for grain iron and zinc concentration among the local germplasm, which could facilitate development of mineral rich bean varieties. For example, analysis of 300 lines from D. R. Congo, Kenya, Uganda, Rwanda and Tanzania showed that iron concentration varied from 40 to 105 ppm. Sixty-six lines had more than 90 ppm indicating that potential of increasing iron concentration in the grain by more than 90%. Analyses of four landraces collected in central and southern Tanzania showed that iron concentration was lowest in white beans (73 ppm) and highest in grey (114 ppm) and yellow beans (120 ppm). Kidney beans had intermediate levels of iron (87 ppm). Bean showed higher iron concentration compared to whole maize (19 ppm), dehulled maize (7 ppm), cassava (5 ppm), cassava flour (5 ppm), cocoyam (4 ppm), potato (3ppm) sweet potato (5 ppm) and cooking bananas (5 ppm), which are widely consumed in the region. Mineral concentration in grey and yellow beans was higher than beef (98 ppm) and comparable to fish (124 ppm). This implied that beans are among the most important sources of iron in local diets, and is critical to the vast majority who have limited access to animal sources.

Table 5. Germplasm accessions collected, characterized and analyzed for mineral density in East and Central Africa, 2003-2008.

Country	Target	Number collected	Number characterized	Number analyzed for Fe and Zn
Burundi	0	27	0	0
DRC-East	700	500	500	300
DRC-West	100	150	150	10
Ethiopia	0	5	5	5
Kenya	400	362	362	282
Madagascar	0	52	52	0
Tanzania	400	177	141	12
Sudan	0	8	8	5
Rwanda	1100	1100	1037	900
Uganda	600	500	125	180
Total	2000	2853	2380	1684

Although mineral density was affected by the growing conditions (soil type, soil nutrients) and methods of analyses, results showed that most of the lines consistently showing high levels of micronutrients originated from the Great Lakes region especially D. R. Congo and Rwanda. Genotypes with high levels of iron included Maharagi Soja, Gofta, AND 620, MLB 49 89A, HRS 545, Nakaja, VCB 87013, Nain de Kyondo, TY 3396-13, PVA 8, Nguaku Nguaku, Urugezi, Lib 1, Roba-1 and Mwamfutala. All except Gofta, Roba-1 (Ethiopia) and HRS 545 (Sudan) originated from the Great Lakes Region. Blair et al. (2007) also reported Nakaja and Urugezi as a high Fe lines. Lines with high levels of zinc included VNB 81010, MLB 49 89A, AND 620, LIB 1, Ranjonoby, Naindeky, Nakaja, Jesca, K131, K132 and Kiang'ara. When these lines were grown under uniform low N conditions in the greenhouse at Kabete, they showed lower levels of Fe (21-81 ppm) and Zn (8-38 ppm) compared with results with original samples. This suggested possible genotype x environment interaction for these traits, or possibly contamination, which is common in work with minerals. Large seeded Andean varieties from SABRN and ECABREN regions had higher Fe concentration than the small seeded Mesoamerican varieties from the same region. Finally, a total of 38 lines were selected for next stage of variety development. These were dubbed 'fast track' lines because they combined high mineral density with other important traits preferred by farmers and consumers, and would therefore require less time for testing before being released as varieties.

Selection of Mineral dense Climbing Varieties. Although the current initiative to develop mineral dense bean lines initially focused on bush bean with marketable grain characteristics, it became necessary to develop a parallel program for the more productive biofortified climbing bean types. Climbing beans typically give a three to four fold yield increase per unit area and can be ideal in urban and rural areas with high population pressure and declining land size. To realize this objective, CIAT introduced advanced climbing bean lines selected for high mineral density (referred to as NUVs) for preliminary observations in primary evaluation sites in east, central and southern Africa. The objective of these trials was to conduct preliminary adaptability trials, and to increase seed for distribution to national programs and communities for further participatory evaluation and eventual release as commercial varieties. In East and Central Africa region, two sets of climbing beans have been introduced and evaluated. The first set of climbing beans originated from fast track nursery which comprised of local landraces, released varieties, and advanced breeding from the national bean programs. This nursery was created in 2001 but new accessions have been added in the last eight years. Genotypes in this nursery were screened for grain iron and zinc concentration. Genotypes with iron levels above 70 ppm and zinc levels above 30 ppm were evaluated in participatory on-farm and on-station trials for agronomic traits and consumer acceptance. The second set of climbing bean lines were NUV lines. They were introduced in eastern Africa in 2007 from CIAT, Colombia. Field evaluation of these lines started in 2007.

First track climbing bean nursery was distributed to nine countries in eastern Africa (ECABREN) from 2003, and to central and west Africa (WECABREN) in 2005, 2006 and 2007. The nursery had type III (semi-climbers) and type IV (climbers). The status of evaluation is shown in Table 6.

Table 6. Status of evaluation of fast track mineral dense climbing beans lines in eastern Africa, December 2008.

Country	Observation trials	Preliminary yield trials	Advanced yield trials	National multi-location trials	Candidates for release
Burundi	Yes	Yes	Yes	In progress	
D. R. Congo (east)	Yes	Yes	Yes	In progress	4
D. R. Congo (west)	Yes	Yes	Yes	In progress	4
Ethiopia	Yes	Yes	-	-	
Kenya	Yes	Yes	Yes	Yes	3
Madagascar	Yes	Yes	In progress		2*
Rwanda	Yes	Yes			
Sudan	Yes	Yes			
Tanzania	Yes	Yes			
Uganda	Yes	Yes			
Cameroon	Yes	Yes	In progress		
Central African Republic	Yes				
Guinea Conakry	Yes				
Congo (Brazzaville)	Yes				

* Madagascar does not have a formal variety release program yet. The two lines (VNB 81010 and M211) were selected from fast track nursery. FOFIFA bean program considers them as pre-releases and seed production with partners started in 2008.

Results show that considerable progress has been made in Burundi, D. R. Congo, Kenya, Madagascar and Cameroon. In Rwanda, one line (G59/1-2) has been selected for advanced yield trials because it combined high yield potential (2.5 to 3.5 t ha^{-1}) with mineral density (110 ppm Fe). More than 2400 kg of seed was produced with partners in Ruhengeri region. In Cameroon, TY 3396-12 with type III growth habit is among the most promising lines from the fast track nursery. In Burundi selection was done in multi-location trials in on-farm and on-station trials in high, medium and low altitude locations. Five climbing bean lines (Nakaja, VNB 81010, VCB 81012, Kiangara and G59/1-2) were selected in 2008 as candidates for final evaluation and seed production. In D. R. Congo, ten climbing bean lines from fast track nursery were selected in participatory variety selection conducted at three high altitude locations in eastern part of the country. They included (in decreasing order of preference) VCB 81013, G59/1-2, AND 10, LIB 1, MLV 224/97B, VCB 81012, VNB 81010, Kiang'ara, MLV 59/97A and MLV 06-90B. Low mineral check M211 was selected in Madagascar, Burundi and D. R. Congo because of its good productivity. In western DRC, four climbers which combined high mineral density and agronomic potential were selected (Table 7).

Table 7. Grain iron, zinc and protein concentration of four climbing bean genotypes adapted to low and medium altitudes selected in western D. R. Congo.

Line	Fe (ppm)	Zn (ppm)	Protein (%)
G59/1-2	90	45	22.9
VCB 81013	95	20	20.8
LIB 1	94	52	-
Kiangara	80	20	20.2

Source: Mbikayi and Lodi Lama, 2008

In Kenya, seven climbing bean candidates from the fast track nursery were evaluated in national performance trials (NPT) conducted at eight locations for two seasons between 2007 and 2008. Regional important cultivars, Vunikingi, Umbano and recent releases (MAC 13, MAC 34 and MAC 64) were used as checks. Four candidate varieties were pre-released (MV 14, MV17, MV18 and MV19). MV 19 was the best yielding. The pre-released lines were evaluated for a second round of NPT in 2008. Table 8 shows a summary of the combined results over the two years.

Three candidate varieties (MV 19, MV17 and MV 14) were recommended for full release in December 2008. This marks the first time bean genotypes selected for micronutrient density reached full release status after independent, multilocation evaluation for agronomic traits. These results also confirmed that it is possible to combine high mineral density with good agronomic potential.

Table 8. Yield of four mineral dense climbing bean lines evaluated in national performance trials at seven locations in Kenya over two years.

Line	Status	Mean yield across environments (kg ha^{-1})	Yield over best check (%)
MV 19	Candidate	2230	45.8
MV17	Candidate	2200	44.1
MV14	Candidate	2150	40.1
MV18	Candidate	1560	2.2
MAC 34	Check	1530	
MAC 13	Check	1190	
MAC 64	Check	1180	
Vunikingi	Check	1110	

Source: KEPHIS, 2008

Evaluation of NUVs. 264 NUV lines were planted in observation trial at Mwea during the 2007 long rain season. Grain yield varied from 420 to more than 3000 kg ha^{-1}. Yield was adversely affected by moisture stress during the flowering and pod filling growth stages. Twenty-five lines had yields of more than 3 t ha^{-1} despite the stress. Some of the best performing lines included NUV 16, NUV 35, NUV 41, NUV 71, NUV 72, NUV 73, NUV 90 and NUV99. This trial also facilitated seed increases. The lines are currently being evaluated in replicated trials at Kabete, Laikipia, Thika and Mwea. Mineral analyses of grain from the observation trial is in progress.

Status of biofortified fast track bush lines: Considerable progress was made during the year in evaluation of fast track bush lines in eastern Africa. Table 9 shows the status of these lines in the region.

Table 9. Status of evaluation of fast track mineral dense bush bean lines, December 2008.

Country	Observation trials	Preliminary yield trials	Advanced yield trials	National multi-location trials	Candidates for release
Burundi	Yes	Yes	Yes	-	
D. R. Congo (east)	Yes	Yes	Yes	In progress	3
D. R. Congo (west)	Yes	Yes	Yes	In progress	
Ethiopia	Yes	Yes	Yes	-	
Kenya	Yes	Yes	Yes	Yes	4
Madagascar	Yes	Yes	-		
Rwanda	Yes	Yes	Yes	-	
Sudan	Yes	Yes	-		
Tanzania	Yes	Yes	Yes	-	
Uganda	Yes	Yes	-		
Cameroon	Yes	Yes	In progress	-	
Central African Republic	Yes				
Guinea Conakry	Yes				
Congo (Brazzaville)	Yes				

In Burundi, fast track lines were evaluated in advanced yield trials at three locations during 2008 A and B seasons. The trial sites were Moso (1250m), Mparambo (800 m) and Murongwe (1500m), representing the major agroecological zones for bean production. Eight lines were selected based on yield, reaction to diseases and adaptation and better performance compared with the local check variety Mukungungu. The selected bush lines were GLP 2, PVA 8, MLB49-89 A, MLB40-89A, Maharagi Soja , Gofta and Nguaku – Nguaku. However, Nguaku Nguaku showed poor performance at the low altitude site due to weak stems and prostrate growth habit, excessive vegetative growth and poor pod load. These lines will be evaluated in on-farm trials in 2009.

In eastern D. R. Congo, eleven lines were selected based on their performance at five locations and farmer evaluations. The selected lines were BRB 194, CODMLB 005, Selian 97, COD MLB 007, Nguaku Nguaku, CODMLB 001, AFR 708, CODMLB 003, Maharagi soja, M'Sole and CODMLB078. BRB 194 was selected by 61% of the participating farmers compared with 52 % for CODMLB 005, 48% for Selian 97, 46% for CODMLB 007 and 14.8% for the check variety. Table 10 shows fast track lines selected in western D. R. Congo. These lines showed wide adaptation from 500 to 1500 m above sea level. HM 21-7 originated from Bilfa nursery and is adapted to low fertility soils and drought. Seed of these lines is being increased.

In Kenya, eight bush lines were submitted for national performance trials in 2007 and 2008. Candidate lines were evaluated by the Kenya Plant Health Inspectorate (KEPHIS) and the national variety release committee in 'highland' and 'lowland' test sites. 'Lowland' sites included Kabete, Embu, Kaguru, Katumani and Thika. 'Highland' sites included Chepkoilel, Kakamega, Kisii, Mabanga and Njoro. Four lines (AND 620 (MN1), Gofta (MN3), TY 3396-12(MN5) and NUA 1(MN9) were pre-released in 2008 based on better performance compared with checks. The performance of these lines in the national performance trials over two years (2007 and 2008) is presented in Table 11.

Table 10. Grain iron, zinc and protein concentration of seven fast track bush bean genotypes adapted to low and medium altitudes selected in western D. R. Congo.

Line	Fe (ppm)	Zn (ppm)	Protein (%)
HM 21-7	90	25	20.2
Nguaku	85	20	20.6
Nguaku			
BRB 194	75	30	22.7
CODMLB 078	55	20	19.4
Maharagi Soja	97	23	-
AND 620	122	26	-
CODMLB 007	40	20	19.7

Source: Mbikayi and Lodi Lama, 2008

Table 11. Grain yield of eight mineral dense lines selected from the Fast track nursery at 10 sites over two years in Kenya.

Genotype	Lowland sites			Highland sites		
	Mean yield ($kg\ ha^{-1}$)	Yield over best check (%)	Yield over mean of checks	Mean yield ($kg\ ha^{-1}$)	Yield over best check	Yield over mean of checks
MN 1 (AND 620)	1150	20.9	33.8	2030	32.6	45.1
MN 3 (Gofta)	1130	18.8	31.5	1960	28.7	45.1
MN 6	1130	18.0	30.6	2800	80.6	97.7
MN 9 (NUA 1)	1010	6.1	17.5	1890	23.3	35.0
MN 5 (TY 3396-12)	880	-7.3	2.6	1150	-24.8	2.6
MN 10	950	-0.1	10.6	1210	-20.5	10.6
MN 2	880	-7.4	2.5	1260	-7.0	2.5
MN 11	510	-46.6	-40.3	1420	-46.6	1.8
GLP 92	950			1380		
GLP 1127	800			1530		
GLP 2	830			1280		

Source: KEPHIS, 2008. GLP 92 (Mwitemania), GLP 1127 (Mwezi Moja) and GLP 2 (Rosecoco) were checks.

In Rwanda, four bush varieties from the fast track nursery were selected in advanced yield trials. These were AND 620, Maharagi Soja, MLB 49 – 89 A and MLB 40– 89A. These lines had mean grain yield of 1 to 1.6 t ha^{-1} in multilocation testing. Seed of the four lines and Gofta was produced in Gitarama, Ruhengeri, Kigali-Ngali, Bugesera and Kibungo regions with partners (NGOs, Ministry of Health and communities) and on-station.

In Tanzania, 11 lines selected from the fast track nursery were evaluated in uniformity cultivar multi-locational trials (UCT).They included GLP 2, Nain de Kyondo, PVA 8, OBA 1, Kirundo, K132, K131, Ranjonomby, Lingot Blanc, RWR 10 and Zebra.

Selection from Segregating Populations. Mineral dense lines derived from fast track nursery, which are susceptible to diseases (anthracnose, angular leaf spot, BCMV, BCMNV and rust) were entered in crossing block to correct the deficiencies. Selection for new combinations with mineral density, resistance to diseases and preferred grain types started at INERA-Mulungu (D. R. Congo), Selian

Agricultural Research Institute (Tanzania) and Kabete (Kenya). At Kabete 8 NUA red mottled lines generated from crosses between CAL96 and mineral dense parents were analyzed for minerals and protein concentration (Table 12). Results showed iron concentration varied from 45 to 75 ppm. Zinc concentration varied from 25 to 50 ppm. At Kabete, seven new populations combining resistance to diseases and marketable grain types were advanced from $F_{2.5}$ to $F_{2.6}$ and $F_{2.7}$. Selected lines showed considerable variation for iron, zinc and protein concentration (Table 13). Several lines with high iron, zinc and protein concentration were identified. Grain iron concentration varied 30 to 105 ppm in lines selected from KAB 2 population, 55 to 125 in KAB 5, 30 to 130 ppm in KAB 6, 30 to 115 in KAB 10, 40 to 115 in KAB 11, 35 to 100 ppm in KAB 12, and 50 to 115 ppm in KAB 13 derived lines. Zinc concentration varied from 10 to 55 ppm among the 300 lines. Protein concentration varied from 17.4% to 28.5%. These results suggested that varieties combining high micronutrient density, resistance to diseases and marketable grain types can be developed from these populations.

Table 12. Iron, zinc and protein concentration of advanced NUA lines, runner bean parental lines and their F_1, F_2 populations and F_3 families in Kenya.

Genotype	**Fe (ppm)**	**Zn (ppm)**	**Protein (%)**
NUA 1	65	50	24.1
NUA 2	75	45	24.8
NUA 3	70	45	26.5
NUA 4	50	40	22.9
NUA 5	45	25	24.1
NUA 6	60	35	24.3
NUA 7	65	50	25.2
NUA 8	55	35	22.9
Runner beans			
Nyeri 1	105	45	19.3
Kinangop 2	60	30	19.7
Kinangop 4 (KIN 4)	45	25	19.8
White Emergo	70	20	18.9
Kinangop 1 (KIN 1)	60	35	21.1
White Emergo x KIN 4 F_1	60	30	21.5
White Emergo x KIN 4 F_2	110	25	17.2
White Emergo x Kenya Local (F_2)	80	35	15.3
Kenya Local x White Emergo (F_3)	60	20	15.5
White Emergo F_2	90	20	17.9
White Emergo x KIN 1 (F_2)	65	25	17.4

Table 13. Iron, zinc and protein concentration in $F_{2.6}$ lines selected from seven bean populations in Kenya.

Population	**No. of lines**	**Fe (ppm)**	**Zn (ppm)**	**Protein (%)**
KAB 02	67	30-120	10-40	18-26
KAB 05	16	55-125	10-35	19-24
KAB 06	70	30-130	10-55	17-24
KAB 10	47	30-115	10-45	19-28
KAB 11	30	40-115	10-40	20-28
KAB 12	25	35-100	10-40	19-24
KAB 13	26	50-115	10-60	21-29
Total	281			

Nutritional evaluation. Seed of the 38 fast track lines was sent to Sokoine University for planting to generate leaves, pods, green shelled beans for mineral analyses. At the University of Nairobi two studies were conducted to assess micronutrient concentration in bean leaves. In the first study, seed and leaves of 72 bean lines of diverse origins grown in 40 farmers fields in Kisii district, Kenya was analyzed for iron , zinc and protein concentration. Results showed that iron concentration in leaves was much higher than in the seeds. Leaf iron concentration varied from 397 ppm in Awash 1 to 2498 ppm in Ngwinurare, with a mean of 1118 ppm. Seed iron concentration varied from 50 ppm (MCM 2001) to 108 ppm (M'Sole). However, the levels of zinc were comparable to that of seeds. Leaf zinc concentration varied from 20 ppm (Sugar 73) to 67 ppm (Ngwinurare). It is significant to note that Ngwinurare is a popular variety in Rwanda. Its leaves and grain are being used by communities in five districts participating in the 'Agriculture, Nutrition and Health collaborative project'. The results suggested that bean leaves which are widely consumed in the region can make a significant contribution to micronutrient nutrition. Preliminary results from the Rwandese project indicate improved micronutrient health status in participating communities.

In the second study, leaves of the 38 lines fast track lines were analyzed for iron, zinc and protein concentration. Results showed that leaf iron concentration varied from 236 ppm in cv. 'Zebra' to 1961 ppm in Kirundo. Leaf zinc concentration varied from 17 ppm in cv. Nguaku Nguaku to 94 ppm in cv. Kiangara. Crude protein varied from 23.7% in Red Wolaita to 35.6% in TY 3396. These results seemed to confirm the first study that bean leaves have much higher iron levels compared to the grain. Results on cooking time, nutrient retention, taste, water absorption have been reported (CIAT, 2007).

Bioavailability of Fe and Zn in bean varieties: Trials were conducted to determine bioavailability of iron and zinc in dry beans and green shelled beans of the 38 fast track lines. The *in vitro* studies were conducted in partnership with Sokoine University of Agriculture, Tanzania. Results showed that bioavailability of iron varied with genotypes (Figures 3 and 6). Iron bioavailability was lowest in Roba (1.1%) and highest in Maharagi Soja (6.6%). Cooking enhanced bioavailability. Bioavailability of Fe in cooked samples varied from 3.9% for VCB 81012 to 6.8% for cooked samples of Maharagi Soja. Bioavailability of zinc also varied with genotypes (Figures 4 and 5). It was lowest in OBA (0.5%) and highest in Ituri Matata (2.5%). Cooking enhanced bioavailability of zinc. Bioavailability of zinc in cooked samples of dry bean varied from 0.4% (M'Mafutala) to 3.9% for G59/1-2. Higher bioavailability was observed in green shelled beans compared to dry mature grains (Figures 3, 4, 5 and 6).

Seed production and Dissemination. Several countries increased seed of fast track lines to facilitate local trials and germplasm exchange with other countries and dissemination to farmers. The regional program in Kenya increased seed of biofortified varieties at Kabete, Thika, Ol Jorok and Laikipia. Seeds were shipped to western and eastern D. R. Congo, Rwanda, KARI-Katumani, Tanzania (Selian Agric Research Institute), Denmark, Sokoine University, Madagascar and Cameroon. More than 9000 kg of five fast track lines (Maharagi Soja, Ngwinurare, AND 620, MLB 40-89A and MLB 49-89A) were produced and distributed to communities in six districts (Ruhuha, Ruhengeri, Gihara, Kigali, Kigoma and Rwamagana) in Rwanda in partnership with the ATDT Health and Agriculture project. Lagrotech Seed Company increased seed of biofortified varieties to facilitate on-farm trials and multilocation on-station trials in western Kenya. D. R. Congo increased seed to meet local needs and shipment to Burundi.

Contributors: Paul Kimani, S. Beebe, M. Blair (CIAT) and Peter Mamiro (Sokoine University of Agriculture)

Collaborators: Nkonko Mbikayi (D. R. Congo), A. Namayanja (Uganda), Rael Karimi(KARI-Katumani), and Bean teams at Kabete, CIAT-Colombia, FOFIFA (Madagascar), ISAR (Rwanda), Martha Nyagaya (CIAT), Lagrotech Seed Company (Kenya).

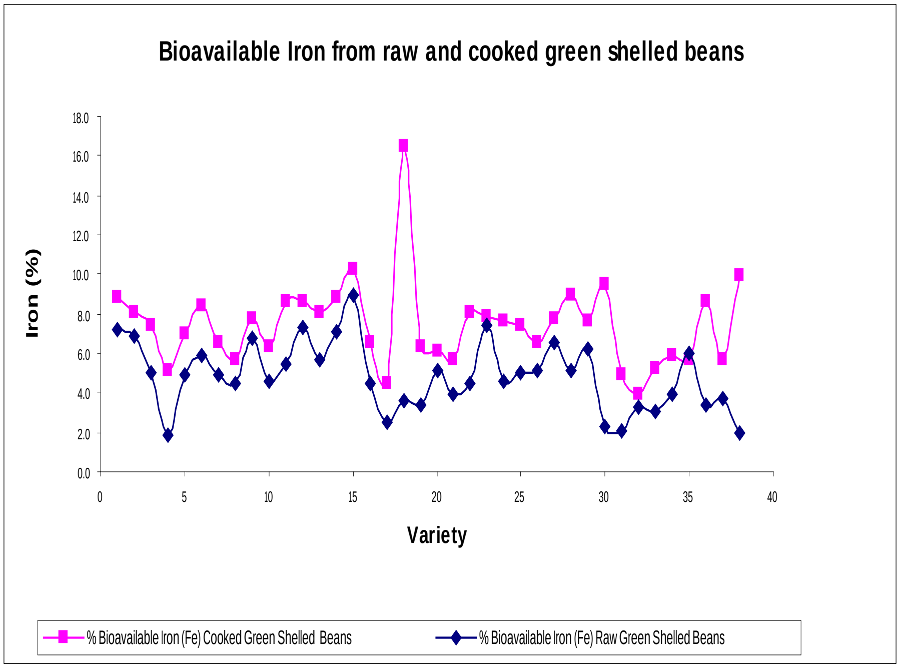


Figure 3. Bioavailable iron from raw and cooked green shelled bean varieties.

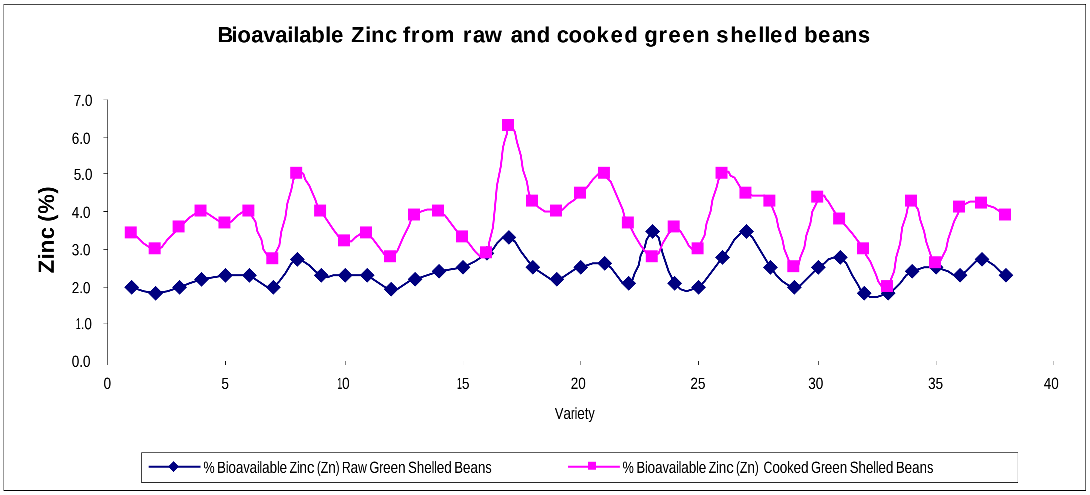


Figure 4. Bioavailable zinc from raw and cooked green shelled bean varieties.

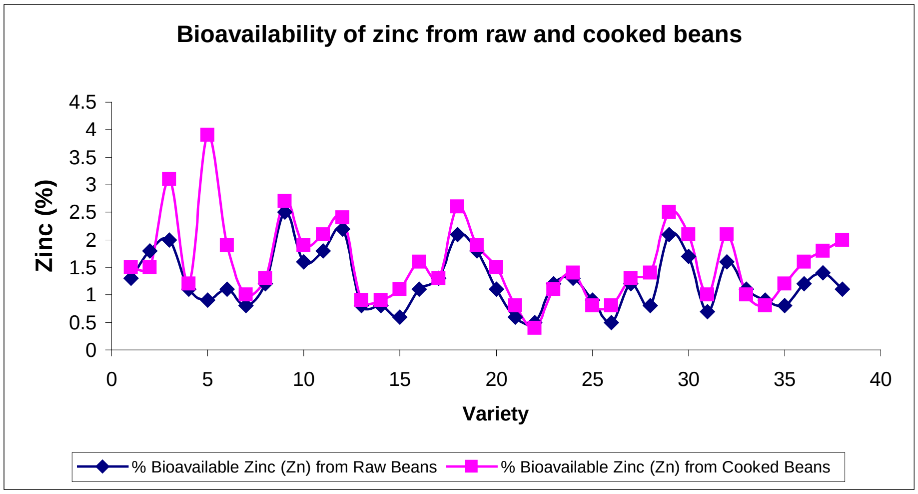


Figure 5. Bioavailable zinc from raw and cooked dry beans of 38 fast track lines.

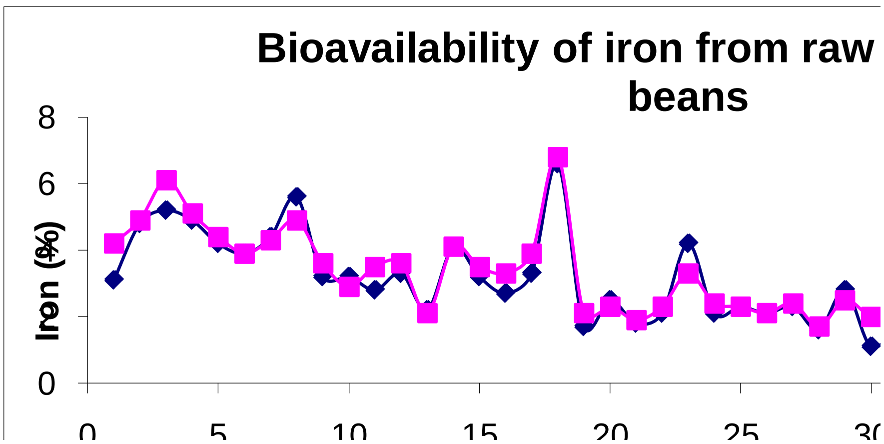


Figure 6. Bioavailable iron from raw and cooked beans of 38 fast track lines.

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Activity 1.2 Genotype x environment interaction

Highlights:

- NUA35 and NUA56 were tested for yield potential and mineral accumulation across 15 sites in Latin America (72 replicates), showing that both lines have a 15 to 25 ppm differential iron advantage over CAL96.
- Significant genotype x environment interactions indicate that grain mineral concentration is influenced by soil type, soil nutrient status, moisture concentration and other environmental factors but the magnitude varies with genotypes. Some genotypes show high stability for mineral density.
- Fertilization regimes and other agronomic practices can be used to enhance expression of high mineral density traits.

1.2.1 Multi-site evaluation of biofortified Andean lines, NUA35 and NUA56

Rationale: Biofortified genotypes of common bean hold promise for improving nutritional status in many countries but require agronomic testing to determine their yield and adaptation potential. Andean biofortified beans from the NUA series have generated interest in various countries of Africa and Latin America and are potential releases for Bolivia, Colombia, Malawi and Zimbabwe. Two sister lines (NUA35 and NUA56) were selected for their high iron and zinc content. Both of these were developed from the high iron source genotype G14519 in backcrosses with the recurrent parent CAL96 and have good red mottled seed type. These genotypes have now been tested over a large number of sites and seasons and this report outlines the iron and zinc levels found in them.

Materials and Methods: Two genotypes, NUA35 and NUA56 were grown across 15 sites and analyzed uniformly for seed mineral content with atomic absorption spectrophotometry (AAS). Before analysis and to reduce variability, seed for each experiment was hand harvested and processed to avoid soil contamination and then shipped to CIAT for analysis where grain was cleaned with a damp cloth. Seed mineral content was evaluated for 4 g of grain dried overnight in an oven at 37ºC. Each sample was then ground into a fine powder using a modified Retsch mill with a teflon capsule chamber and zirconium grinding balls. Mineral content is reported in parts per million (ppm), equivalent to mg of iron or zinc per kg of seed.

Results and Discussion: Mean seed yield for NUA35 at a moderate-elevation/rainfall site in Colombia (Darién at 1459 masl with 20°C seasonal average temperature, 1328 mm average yearly rainfall, with soil pH 5.5-6.0 and 5 to 8 % organic matter) was 1099 kg ha^{-1} with a range from 632 to 1787 kg ha^{-1} over 6 seasons (given bimodal yearly rainfall at this sites, the line was tested over three and a half years over both March - June and September - January growing seasons). The mean seed yield of NUA56 at this same site was 1076 kg ha^{-1} with a range of 704 to 2095 kg ha^{-1} over 5 seasons. In comparison, control genotypes AFR612 and CAL96 yield between 700 and 1800 kg ha^{-1} at this site.

At a high rainfall site in Colombia (Popayán at 1725 masl with 17°C seasonal average temperature, 1991 mm average yearly rainfall with soil pH 5.5-6.0 and 10 to 20 % organic matter), mean seed yield for NUA35 was 1521 kg ha^{-1} with a range from 719 to 2810 kg ha^{-1} while mean seed yield for NUA56 was 1324 kg ha^{-1} with a range from 526 to 2839 kg ha^{-1}. At a lower elevation site in Colombia (Palmira at 967 masl with 24°C seasonal average temperature, 1043 mm average yearly rainfall, soil pH 7.0-7.5 and 2 to 4 % organic matter), mean yields for NUA35 and NUA56 were 946 and 810 kg ha^{-1}, respectively.

Meanwhile, in Santa Cruz, Bolivia (Andres Ibañez at 398 masl with 24°C seasonal average temperature and 1406 mm average yearly rainfall with soil pH 6.0-6.5 and <2 % organic matter), average yields for

NUA35 and NUA56 were 1265 and 1452 kg ha^{-1}, respectively, both surpassing the average yield of the control genotype, CAL96, with a yield of 997 kg ha^{-1} but beneath the average yield of a local check, 'Rojo Oriental' a released variety based on CIAT line PVA773, with 2000 kg ha^{-1}.

Nutrition quality evaluations for seed iron and zinc content (Table 14) showed that the NUA lines always produced more than the average amount of iron for common bean which is 55 ppm; and close to the average amount of zinc for the crop which is 35 ppm. While both lines were high in iron, NUA56 had somewhat higher average seed iron content (81 ppm) than NUA35 (76 ppm) across the 15 sites where the genotypes were tested; while the opposite was true for average seed zinc content where NUA35 had 34 ppm and NUA56 had 33 ppm. Considering that Andean beans usually have lower than average seed zinc content, this amount of zinc can be considered moderate within the genepool.

Table 14 also shows that iron levels in the NUA lines responded to environmental effects with variability for iron from 53 to 101 ppm for NUA35 and 61 to 112 for NUA56, with highest concentrations reached in Santa Cruz, Bolivia and Yacuanquer, Colombia. In comparison, zinc content was fairly stable varying from 28 to 43 ppm for NUA35 and from 25 to 43 ppm for NUA56 with the same sites mentioned for iron producing high seed concentrations of zinc. The iron differential of the two germplasm lines compared to the recurrent parent CAL96 was usually 15 to 20 ppm with up to 25 ppm difference for NUA35 in Santa Cruz, Bolivia and 37 ppm for NUA56 in Yacuanquer, Colombia; while the zinc differential was less substantial**.**

Conclusions and Future Plans: NUA35 is being considered for release in Colombia and Bolivia so the results presented here are timely. Promotion will continue by FIDAR, IPRA/CIAT and partners. The seed color of the NUA lines is very acceptable as they have the same deep red color that is noteworthy of CAL96 the recurrent parent used for development of the NUA lines evaluated so far. The environmental factors that affect iron accumulation at the different sites used for multiplication or testing of NUA lines will be further studied.

Contributors: M.W. Blair, F. Monserrate, C. Astudillo, S. Beebe (SBA-1, CIAT) G. Hyman (GIS, CIAT), J. Restrepo, P. Ojeda (FIDAR), J. Ortubé, V. Choque, J. Padilla (UAGRM, Bolivia)

Table 14. Seed iron and zinc concentration[1] (in ppm) for CAL96 (released variety) versus NUA35 and NUA56 (high iron advance lines) grown over 15 sites in Latin America.

Location (Department, Country)	Seasons	Replications	Latitude (dd°mm')	Altitude (masl)	CAL 96				NUA 35				NUA 56			
					Iron (ppm)		Zinc (ppm)		Iron (ppm)		Zinc (ppm)		Iron (ppm)		Zinc (ppm)	
					Avg.	CV	Avg.	CV	Avg.	CV	Avg.	CV	Avg.	CV	Avg.	CV
A. Ibañez (Santa Cruz,Bolivia)	1	1	17°42.51' S	398	75	-	32	-	99	-	41	-	95	-	34	-
San Juan (Santa Cruz, Bolivia)	1	1	17°57.00' S	1557	92	-	33	-	101	-	34	-	100	-	30	-
Darién (Valle, Colombia)	6	18	3°55.73' N	1459	56	0.18	23	0.14	69	0.16	28	0.12	61	0.18	25	0.15
Palmira (Valle, Colombia)	4	12	3°30.26' N	967	53	0.15	23	0.18	70	0.16	29	0.11	75	0.22	27	0.12
Yotoco (Valle, Colombia)	1	1	3°59.88' N	1459	63	0.12	30	0.07	71	-	43	-	-	-	-	-
Vijes (Valle, Colombia)	1	1	3°43.99' N	1564	-	-	-	-	53	-	31	-	-	-	-	-
Sandoná (Nariño, Colombia)	1	3	1°15.71' N	1674	65	0.03	27	0.04	83	0.02	33	0	82	0.09	36	0.16
Yacuanquer (Nariño, Colombia)	2	4	1°8.66' N	2032	62	0.11	28	0.08	83	0.17	37	0.12	112	0.03	43	0.03
Consacá (Nariño, Colombia)	3	4	1°13.51' N	2277	65	0.01	28	0.01	67	0.23	30	0.23	81	0.11	36	0.03
Popayán (Cauca, Colombia)	5	15	2°31.36' N	1725	50	0.16	23	0.18	73	0.11	30	0.14	67	0.13	25	0.19
Quilichao (Cauca, Colombia)	3	3	3°44.44' N	993	50	0.22	24	0.12	64	0.23	29	0.18	78	0.12	29	0.19
Caldono (Cauca, Colombia)	2	2	2°48.10' N	1508	57	0.08	32	0.03	79	0.14	35	0.04	-	-	-	-
Puriscal (San Jose, Costa Rica)	1	1	9°51.00'' N	1083	47	-	24	-	70	-	34	-	84	-	34	-
Quesada (Jutiapa, Guatemala)	1	3	14°17.85' N	963	69	0.15	30	0.06	95	0.08	38	0.13	89	0.09	39	0.14
Chinantenango (Guatemala)	1	3	14°49.33' N	1801	65	0.21	29	0.19	92	0.16	39	0.19	75	0.11	32	0.18
Average across sites	33	72	NA	NA	58	0.18	26	0.17	76	0.14	34	0.12	81	0.13	33	0.15

[1] Iron and zinc content were determined by atomic absorption spectrophotometry by the CIAT analytical services lab. To avoid variability seed for each experiment was hand harvested and processed to avoid contamination and then shipped to CIAT for analysis where seed mineral content was evaluated by grinding 4 g of grain from each sample into a fine powder using a modified Retsch mill with a teflon capsule chamber and zirconium grinding balls. Powder was transferred to 25 ml plastic tubes and analyzed for both iron and zinc concentration measured in parts per million (ppm) with a wet digestion method. NA = not applicable.

1.2.2 Genotype x environment interactions for grain Fe and Zinc concentration

Rationale: Biofortification seeks to alleviate micronutrient deficiencies through the development, production and consumption of mineral rich varieties on-farm and across agricultural regions. Bean programs in east, central and southern Africa recently embarked on developing nutrient rich and stable bean varieties which can contribute to alleviation of micronutrient malnutrition in the region (CIAT, 2002). Initial activities focused on screening available germplasm for genetic variation in iron and zinc (CIAT, 2003). These studies showed that considerable variation exists to increase seed iron concentration by more than 80% and zinc by 50%. Thirty-eight promising lines were selected following screening of landraces, advanced lines and varieties grown in eastern Africa (CIAT, 2005). However, stability of micronutrient density in bean cultivars across environments is not well known. Productivity and stability in the diverse bean growing environments is influenced by many environmental factors. Soil fertility factors are among the most important influences. Plants require considerable amounts of macronutrients such as phosphorus, nitrogen and potassium. Comprehensive agronomic approaches including specific fertilization strategies to enhance seed nutrient concentration have yet to be pursued (Rengel at al, 1999). However, fertilization aimed at increasing grain nutrient density to allow good establishment when the seed is sown in nutrient-deficient soil has been reported occasionally. Limited literature indicates that fertilization with inorganic and organic forms of micronutrients has potential to increase their concentration in grain. For example, Marschner (1995) showed that concentrations of Zn and Fe in cereal grain increased with an increase in Zn or Fe fertilizer additions. Addition of macronutrients (N, P and K) which promote root and shoot development, can increase the uptake of all nutrients required by the plant (Constant and Seldrick, 1991; Rengel et al, 1999).

Soils in many bean growing environments in East, Central and Southern Africa are deficient in soil phosphorus, nitrogen and potassium and are acidic (pH below 6.5). Recent information indicates that concentration of iron and zinc in seeds is influenced by several quantitative loci (CIAT, 2005). It would therefore be expected that mineral density traits are determined not only by the genotype, but also may be influenced by environmental factors and the differential response of genotypes to agronomic management, soil and climatic factors. To test this hypothesis, studies were conducted to determine the influence of soil type, season, inorganic soil amendments (phosphorus, nitrogen, potassium, iron and zinc) on seed iron and zinc concentration and the associated genotype x environment interactions. Effects of N, P and K fertilization were reported in 2006. In 2008 trials were planted to confirm earlier results.

Materials and Methods: Ten bean lines were grown at four levels of N, P, K fertilization at three locations in Kenya during the short rain season (November to February) and long rain season (April-August). The bean lines included nine with high levels of iron and/or zinc, and a check (M211). P treatments were 0, 25, 50, 75 kg P ha^{-1}. Source of P was triple super phosphate (46% P_2O_5) fertilizer. The four N levels were 0, 50, 100 and 150 kg N ha^{-1}. Potassium was applied at 0, 50, 100 and 150 kg ha^{-1}. Potassium fertilizer in the form of potassium sulphate (K_2SO_4-50%K_2O) was preferred to potassium chloride (KCL) because the SO_4^{-2} ion enhances phosphorus. Fertilizer was applied in the furrows and thoroughly mixed with the soil before planting. The factorial experiments were laid out a split-plot with three replicates. Varieties were the main plots and N, P, K and lime levels, the subplots. A plot consisted of 3 m rows. Spacing was 45 cm between rows and 10 cm within rows. The trial was conducted at Thika (1548 masl) and Kabete (Field 16, 1849 masl) during the short rain season, and at Kakamega (1583 masl) and Kabete (Field 10, 1794masl) in the long rain season. Soils at Kabete are humic nitisols (FAO, 1990; Jaetzold and Schmidt, 1983), slightly acidic (pH 5.5) and deficient in available phosphorus and nitrogen (Mwaura, 1995). Soils at Thika are eutric nitosols and acrisols, and low in nitrogen and phosphorus. At Kakamega soils are Dystro-Mollic nitisols, low in phosphorus (MOA, 1987; Siderius and Muchena, 1977). Soil samples were collected at each site before planting. Leaf samples were collected before flowering. Seed samples for mineral analyses were taken at harvest. Ground samples were digested with hydrogen peroxide, sulphuric acid and salicylic acid following methods of Novozamsky et al. (1983) and

Okalebo et al. (2002), and read on atomic absorption spectrophotometer (Perkin-Elmer Corporation, USA). Data was collected on phenology, disease incidence, 100-seed mass and grain yield following the CIAT standard scale (Schoohoven and Pastor-Corrales, 1987). Genstat (2005) software was used for analyses of variance.

Results and Discussion: Results showed that there significant location, season, treatment and genotypic effects on the grain iron and zinc concentration. Significant genotype x environment interactions were detected.

N effects. Fertilization with N up to 100 kg N ha^{-1} increased grain Fe and Zn concentration in all four environments. This result is similar to that obtained in 2006. However, grain mineral density varied with locations and seasons. Figures 7 and 8 illustrate genotypic differences averaged over N treatments.

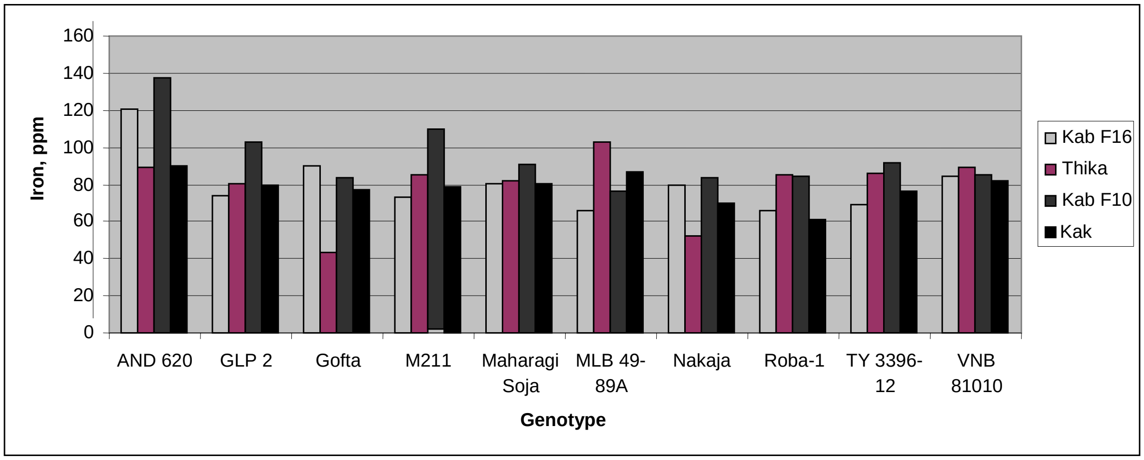
P Effects. Phosphorus fertilization significantly ($P<0.05$) increased seed Fe concentration. Results showed that grain iron concentration increased with P fertilizer application up to 50 kg P ha^{-1} rate for bean lines grown in Kabete Field 16, Thika and Kabete Field 10. However, at Kakamega, grain iron concentration increased with P fertilization up to 25 kg P ha^{-1}. Application of P at 75 kg P ha^{-1} rate led to a decline in seed Fe concentration in all the sites for the two seasons. This is similar to the pattern observed in 2006, although in that year iron continued to increase at 75 kg ha^{-1} except at Kakamega. Genotype x environment interaction effects on grain Fe concentration are shown in Figure 9.

K effects. Mean seed Fe increased but not significantly with increasing levels of K up to 150 kg K ha^{-1}. In 2006 also, response of grain iron to K application was minimal. AND 620 had the highest grain iron concentration when grown at Kabete 16 (105 ppm), while the lowest grain concentration was observed for TY 3396-12 grown at Thika (Figure 10). Zn concentration increased significantly ($P<0.05$) with increasing levels of K up to 150 kg K ha^{-1}. In 2006 an increase was also noted, but not at the highest level of K application. VNB 81010 showed the highest Zn concentration (34.3 ppm) when grown in Kabete Field 10, while lowest Zn levels were recorded from Roba-1 (19.6) grown in Kabete Field 16 (Figure 11). The results obtained indicate that adequate levels of K have the potential to increase bean yields, seed iron and zinc concentrations. However, the significant genotype x environment interactions suggest that grain mineral density varies with locations and genotypes.

In general, results in 2008 were consistent with previous results. N and P gave the most dramatic increases in grain iron, while K application gave modest increases in seed zinc.

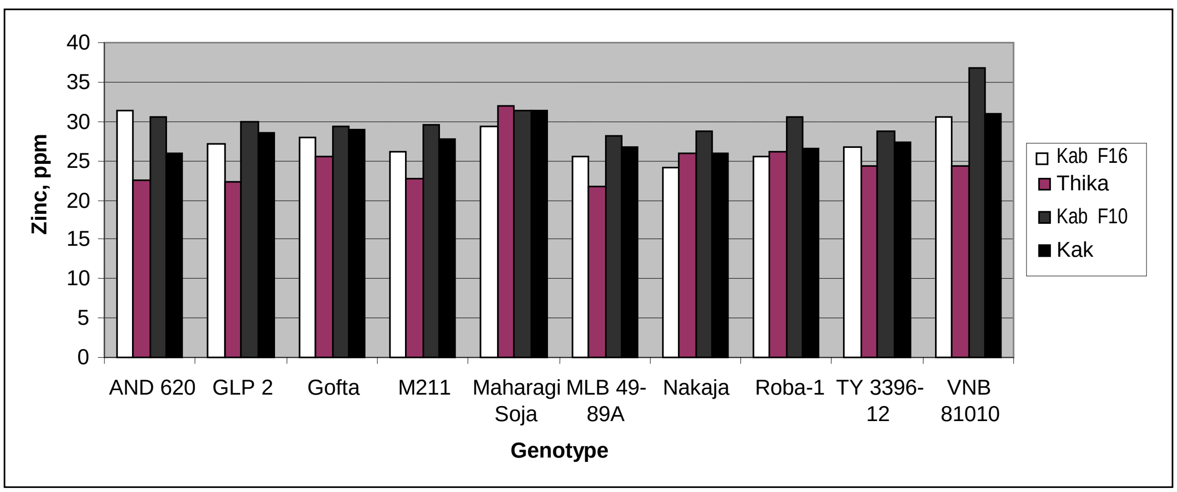
Contributors: Paul Kimani, Ben Okonda, J. K. Keter and S. Beebe

Collaborators: Bean Team at Kabete, Kenya.



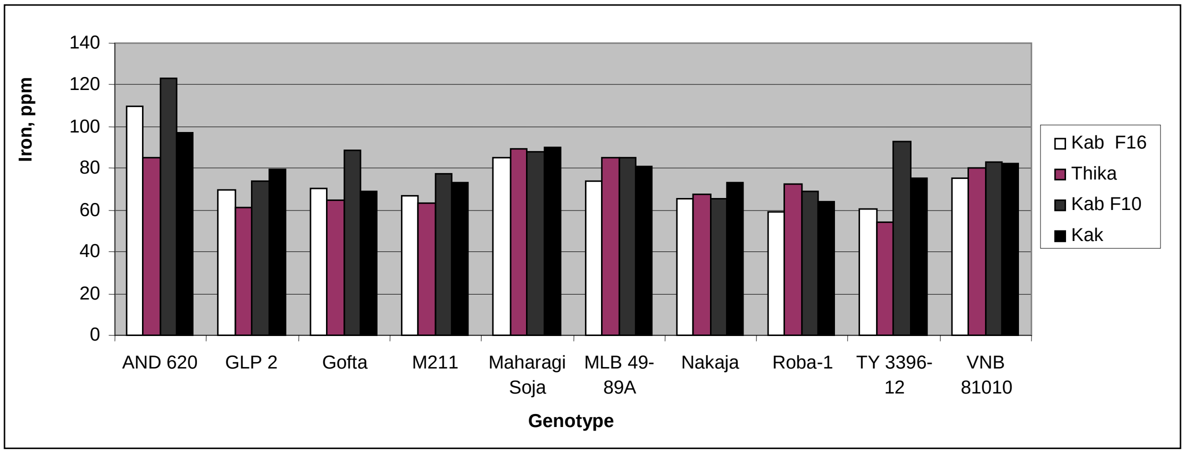
Kab F10= Kabete Field 10, Kab F16= Kabete Field 16, Kak= Kakamega. Average of four levels of N fertilization.

Figure 7. Genotypic x environment interactions for seed iron concentration of ten bean lines grown in four environments at four N levels for two seasons.



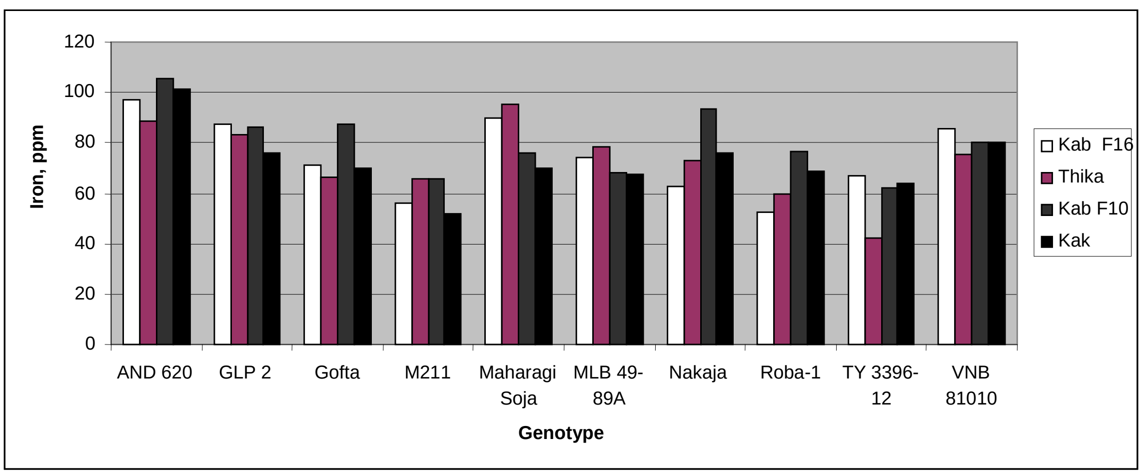
Kab F10= Kabete Field 10, Kab F16= Kabete Field 16, Kak= Kakamega. Average of four levels of N fertilization.

Figure 8. Genotypic x environment interactions for grain zinc concentration of ten bean genotypes grown at four N levels in four locations for two seasons.



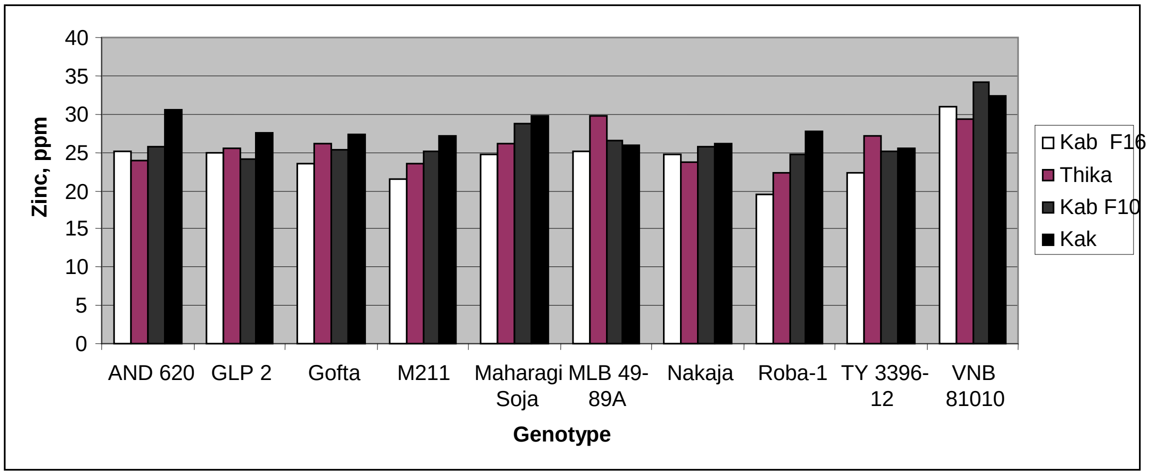
Kab F16= Kabete Field 16, short rain season; Kab F10= Kabete Field 10, long rain season; Thika= KARI-Thika, short rain, and Kak= KARI-Kakamega, long rain.

Figure 9. Genotypic x environment interactions for seed iron concentration of 10 bean lines grown at four P levels in four locations over two seasons.



Kab F16= Kabete Field 16, short rain season; Kab F10= Kabete Field 10, long rain season; Thika= KARI-Thika, short rain season and Kak= Kakamega, long rain.

Figure 10. Genotypic x environment interactions for seed iron concentration of ten bean genotypes grown at four potassium levels in four environments for two seasons.



Kab F16= Kabete Field 16, short rain season; Kab F10= Kabete Field 10, long rain season; Thika= Thika, short rain season, and Kak=Kakamega, long rain season.

Figure 11. Genotypic x environment interactions for seed zinc concentration of ten bean lines grown at four potassium levels in four environments over two seasons

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Activity 1.3 Associated traits: antinutrients

Highlights:

- The inheritance of seed phytate content was analyzed to determine if this anti-nutrient could be reduced and how it is related to seed phosphorus content. Quantitative inheritance was found with several QTL explaining both traits independent of seed size. The results of this study show some genotypes with low levels of phytates which would seem to be sufficient for breeding attempts. The other anti-nutrient being analyzed is condensed tannins and an HPLC method was adapted to look at the tannin monomers that accumulate in genotypes from an inter-genepool population.

1.3.1 Inheritance of seed phosphorus and seed phytate content in a recombinant inbred line population of common bean

Rationale: Phytates are an important anti-nutritional component of legume seeds because they chelate mineral uptake in human digestion. Phytates can also bind certain charged proteins making them less digestible as well and the lack of phytase production in monogastric digestive systems prevents phytates from being hydrolyzed and utilized by humans. On the other hand phytates are important as a seed supply of phosphorus and as a health-promoting factor in some human populations susceptible to diseases such as heart disease and certain cancers. It is notable that phytate levels are often correlated with total seed phosphorus (P) and are the main storage form of P in plant seeds with phytates representing 65% or more of the P present in cereal or legume grain; and therefore both seed P and phytates are characteristics that should be considered jointly. From this perspective our goal has been to understand the inheritance of phytate content and its relationship with seed phosphorus in common bean seeds. The objective of this research was to evaluate quantitative trait loci (QTL) for seed phosphorus and phytate content in an inter-genepool (G2333 x G19839) recombinant inbred line population of common bean

Materials and Methods:

Plant material: An inter-genepool recombinant inbred line population derived from the cross of G2333 (Mesoamerican, type IV climbing bean from Mexico) by G19839 (Andean, type III bush bean from Peru) and consisting of 84 $F_{5:8}$ lines was grown in two experiments in Popayán, Colombia in the 2004 growing season on soils that are inceptisols with a native P content of 2 ppm which is considered deficient. The two experiments differed in P fertilization: a total of 200 kg ha^{-1} of 10-30-10 N-P-K fertilizer was applied for a medium phosphorus treatment and 400 kg ha^{-1} was applied for a high phosphorus treatment. The two levels of phosphorus fertilization were used since P supply is thought to influence seed phytate content. All other agronomic management except for P supply was the same for the two trials with plants grown on trellises and plot size consisting of double rows that were 3 m in length and 2 m wide. Both medium and high P experiments were randomized complete block designs with two repetitions each and included the parents as control genotypes.

Seed P and phytate analysis*:* Seed was hand harvested from each plot at full maturity, dried to 12% humidity prior to storage at 4ºC and used in seed phytate and total phosphorus analysis. Seed P and phytate content were quantified with spectro-photometric methods based on acid digestion with molybdenum blue and Wade reagents, respectively, and net seed P and net phytate content were calculated on a per seed basis using seed weights for each experiment.

Data analysis: Analyses of variance were conducted for the seed phosphorus and seed phytate concentration traits in the RIL genotypes and parents across the two environments (medium P and high P fertilization) using SAS with all effects considered random and each term assumed to be independent.

The means for each genotype in each environment were used for quantitative trait locus (QTL) analysis with the probability of a QTL being present expressed in terms of LR (likelihood ratio) values.

Results and Discussion:

The molybdenum blue / Wade reagent method was found to be rapid as a quantification technique for total phytates, compared to more expensive, time consuming and multi-step analyses implemented for common beans with high pressure liquid chromatography (HPLC). In addition, the solid phase extraction column was found to be highly reproducible and coefficients of variation for the genotypes with this method were less than 5%. The analyses of variance showed significant differences between RIL genotypes for seed weight, total seed phosphorus, percentage seed phytate, net seed phytate and net seed phosphorous (Table 15). Total seed P in the RILs varied from 2.8 to 6.1 g kg^{-1} and phytates varied from 0.29 to 1.78 % across fertilization levels. Calculations of net phytate and net P content were used to evaluate the amount of phytate or phosphorus per seed rather than on the percentage bases as described above. This was justified by the fact that we analyzed a Mesoamerican x Andean inter genepool population that segregated widely for seed size and by the hypothesis that larger seeds serve to store greater amounts of nutrients than smaller seeds but that nutrient requirements are similar for seedling establishment. Given the larger average seed size of G19839 (0.62 to 0.73 g seed^{-1}), this parent had up to 100% higher net phytate and net P content than G2333 (0.29 to 0.31 g seed^{-1}) under both soil P levels.

Table 15. Range for seed phytate content, total seed phosphorus (P), seed weight, net seed phytate and net seed P content in recombinant inbred line population G2333 x G19839 grown in two experiments in Popayán under high (HP) and medium phosphorus (MP) soil fertilization.

Trait	P level	RILs Mean	Range	P_{RILs}
Seed Phytate (%)	HP	0.93 ± 0.31	0.29 - 1.78	*
	MP	0.94 ± 0.48	0.29 - 1.76	*
Total Seed P (g kg^{-1})	HP	4.22 ± 0.52	2.75 - 6.06	***
	MP	4.23 ± 0.45	3.11 - 5.95	***
Seed Weight (g)	HP	0.40 ± 0.08	0.24 - 0.67	***
	MP	0.39 ± 0.08	0.25 - 0.65	***
Net Phytate Content (mg seed^{-1})	HP	0.37 ± 0.15	0.88 - 9.26	***
	MP	0.38 ± 0.22	0.87 - 8.26	***
Net P Content (mg seed $^{-1}$)	HP	1.69 ± 0.41	0.78 - 2.97	***
	MP	1.69 ± 0.39	0.94 - 2.90	***

* and *** , significance at probability levels of 95% and 99.9%.

Population histograms for percentage total seed phosphorus, percentage phosphorus, net phytate content, net seed P content and seed size in the G2333 x G19839 RILs were normally distributed in both environments and there was no evidence of kurtosis or skewing in any of the histograms. These results suggest that all of the traits measured were inherited in a quantitative manner. In each case, parental means tended to be less distinct than the lowest and highest seed P or phytate containing RILs suggesting that transgressive segregation was important in the inheritance of the traits and that both parents contributed positive and negative alleles for the traits. A total of six QTL were found for total or net seed P while three were found for percentage or net seed phytates. In addition six QTL were found for seed weight. QTL for seed P and percent phytates were located independently. Meanwhile the QTL for net seed P or phytate content were related to seed weight QTL. The QTL were of moderate effect and the phytate and seed P QTL were independent of each other and of QTL for seed size.

Conclusions and Future Plans: The ability to select QTL for seed phosphorus or phytate separately is important since seed phosphorus is important for plant growth while phytate is a major factor influencing the bioavailability of iron, zinc and calcium. The results of this study show that some genotypes have levels of phytates which would seem to be sufficiently low for breeding attempts. Furthermore, the results suggest that bean plants can adapt to different initial supplies of phosphorus and that seed P and phytate levels in common bean can be modified through plant breeding. We plan to use the methodology developed here to evaluate additional populations and to consider marker assisted selection strategies for reducing phytates while maintaining seed P levels. We are also exploring candidate genes for phytate content as potentially suitable markers for this work in the future.

Contributors: Blair MW, Sandoval TA, Caldas GV (SBA-2-CIAT), Beebe SE (SBA-1, CIAT) , Páez MI (Univalle)

1.3.2 Analysis of condensed tannins through HPLC in genotypes from an inter-genepool bean population

Introduction:

Seed coat color in *P. vulgaris* is determined by the amount and presence of flavonol glycosides, tannins and anthocyanins. These compounds are synthesized by the flavonoid pathway and although the pathway is well characterized in some species, in common bean the genes are not yet well known. On the other hand, extensive genetic analyses have identified specific Mendelian genes that control seed coat pattern and color. However, it has not been possible to identify the genes responsible for producing specific flavonoid compounds. This means that until now the relationship between genes which control the enzymes in the pathway and the Mendelian genes for seed coat color is not clear. With this in mind and because of our previous studies on QTL mapping for tannin content, we decided to begin analyses in tannin composition on some genotypes from the DOR364 x G19833 bean population.

Materials and Methods:

<u>Plant Materials:</u> We chose 20 genotypes from the DOR364 x G19833 population with contrasting seed colors ranging from red to yellow to brown. The population was harvested in Darién 2006 with three repetitions by genotype. The genotypes were contrasting in tannin content. Samples of 10 seeds each were analyzed for each genotype. The seeds were peeled and the seed coats were ground for analysis.

<u>HPLC analysis:</u> Condensed tannins were extracted using 70% acetone and converted to anthocyanidins by the butanol-HCl method in triplicates. For the HPLC analysis we dried 1mL of each sample after the reaction with butanol-HCl in a sample concentrator. The dried samples were re-dissolved in a methanol-HCl 1% solution, filtered (Millipore PTFE, 0.45uM) and placed in a vial for the injection. Separation of anthocyanidins (resulting from the de-polymerizing of the tannins via butanol-HCl method) was achieved using a 8 x 100 mm Nova-Pack C18 column (4um, Waters). The solvents were A, 100% Methanol and B, 5% acetic acid. The gradient consisted of: 40% B for 1 min, 30% B for 1.3 min, 35% B for 20 sec, 40% B for 1.3 min, 60% B for 2 min. Detection was carried out in a UV detector (Shimadzu CL-10A) using 530nm as wavelength.

<u>Data Analysis:</u> The standards that we used for the identification were the three anthocyanidins, cyanidin chloride, delphinidin chloride and pelargonidin chloride (Supplied by Apin Chem Ltd, Abington, UK). The control sample was the standard cyanidin chloride and the data were analyzed by Statistix v.8.0. Overall, we collected 567 datapoints and these were expressed as area percentage of each anthocyanidin and also as seed coat percentage.

Results and Discussion:

The chromatographic analysis of the samples treated with butanol-HCl, showed the existence of 3 principal anthocyanidins (Figure 12). The retention times for delphinidin, cyanidin and pelargonidin were 2.18, 2.9 and 3.5 minutes respectively. Analysis of variance for each trait indicated the existence of significant variability among the chosen genotypes (Table 16). This analysis was based in the data expressed as percentage of anthocyanidin in seedcoat. The highest anthocyanidin in content was cyanidin, followed by delphinidin and then perlargonidin, indicating that in the analyzed genotypes the most representative monomer was catequin. Pelargonidin was significant only in a few cases.

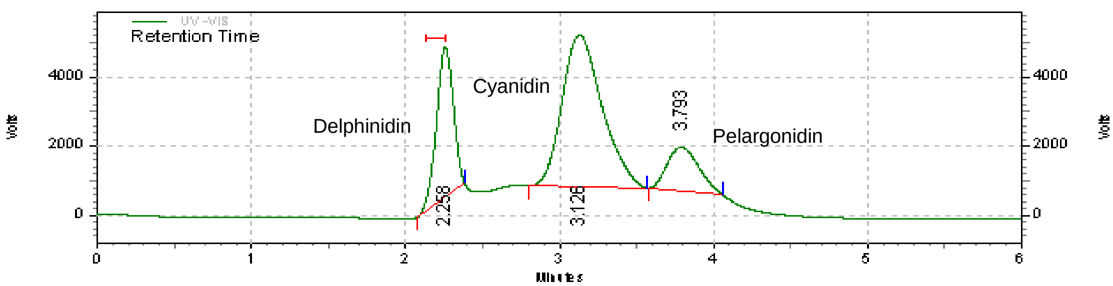

Figure 12. Chromatogram of a bean sample through HPLC analysis for the quantification of anthocyanidins.

Table 16. Analysis of variance for three types of anthocyanidins in common bean seed coats of 20 genotypes and one control.

Trait	Source	DF	SS	MS	F	P
Delphinidin	Genotype	20	0.43896	0.02195	2.58**	0.0048
	Error	42	0.35693	0.00850		
	Total	62	0.79590			
Cyanidin	Genotype	20	0.05079	0.00254	3.04**	0.0012
	Error	42	0.03506	0.00083		
	Total	62	0.08585			
Pelargonidin	Genotype	20	0.04274	0.00214	1.83**	0.0487
	Error	42	0.04892	0.00116		
	Total	62	0.09166			

** Asterisks indicate significance at the 0.05 probability level

Overall, the red genotypes had less amount of cyanidin and were the highest in pelargonidin content, whereas the other colors had similar content in the three anthocyanidins. However, according to our results, the proportion of anthocyanidins related to the type of monomer in the tannin polymer changed notably among field repetitions. Thus, in some genotypes it was possible to observe traces of pelargonidin in just one of the field repetitions. In terms of anthocyanidin content in the seed coat, the average for cyanidin was 0.19%, for delphinidin was 0.13% and for pelargonidin was 0.04%. A sample of cyanidin chloride was run during each analysis as a control, the standard error and coefficient of variation was 0.07 and 3.7% respectively, indicating the suitability and reproducibility of the method.

Conclusions and Future Plans:

The differences between genotypes evidence the existence of segregation in the population for tannin composition; therefore the next step is the evaluation of the entire population in order to carry out QTL analysis. The information about the regions which control condensed tannins, will be more specific and along with the anthocyanin analysis we could establish regions in the genome, specific for steps in the pathway and at the same time a type of association between them and the Mendelian genes for seed coat color. Future activities are QTL analysis for tannin monomer composition and anthocyanin content in the DOR364 x G19833 population.

Collaborators: A.M. Díaz, G.V. Caldas, M.W. Blair

Product 2: Beans that are more productive in smallholder systems of poor farmers

Activity 2.1 Developing germplasm tolerant to abiotic stresses

2.1.1 Drought resistance

Highlights:

- Mesoamerican crosses among drought resistant parents that had expressed a degree of tolerance to low soil P availability, produced more than 20 lines that were excellent in drought resistance. Some lines subsequently showed adaptation to low P in Darién, producing grain of excellent quality under combined drought and low P stress.
- Another 15 Mesoamerican families combined drought tolerance and *bc*-3 gene for resistance to BCMNV.
- In an effort to incorporate drought tolerance in Andean bush beans we have created a series of 216 advanced drought Andean beans (DAB) lines from inter and intra-gene pool crosses involving 5 commercial genotypes from Southern Africa and 10 drought tolerance sources of which half were Andean and half were Mesoamerican to produce 46 populations. The lines represent large red, red mottled and cream mottled seed types. Selection has stressed bush bean architecture, adaptation to drought stress and yield potential under favorable conditions using alternate dry versus rainy season plantings.
- A reference collection of landraces from the CIAT core collection has been evaluated in the field for drought tolerance compared to a series of check genotypes. The reference collection was stratified into Andean and Mesoamerican gene pools and the association of drought tolerance with subgroups and common bean races was analyzed.
- Mid-elevation adaptation was tested in Darién for a series of SAB (drought resistant Andean) lines originally developed from crosses between the drought-resistant genotypes SAB 258, SAB 259, and ICA Quimbaya crossed with drought susceptible but commercial type genotypes ABA36, ABA58 and COS16. Results confirmed the genetic gain for drought tolerance and yield potential that has occurred in the breeding of the SAB lines compared to both their drought-tolerant and susceptible parents. The same lines were tested in rainfed conditions in Palmira and several maintained their yield advantage over local checks. Certain SAB lines can be selected with greater stability across mid-elevation and lower-elevation sites based on this analysis.
- Field evaluation of elite lines at Palmira resulted in identification of five lines NCB 226, SEN 56, SER 113, SER 125 and SER 16 that were outstanding in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of harvest index, pod harvest index, leaf area index and canopy biomass. The SER lines that were developed in the last few years seem to combine the desirable traits for drought adaptation such as greater mobilization of photosynthates to seed with efficient use of water through stomatal control.
- Field evaluation of 33 RILs of the cross DOR 364 x BAT 477 at Palmira over two seasons under terminal drought stress conditions resulted in identification of two lines (BT 21138-17-1-1 and BT 21138-6-1-1) that were superior in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of harvest index, pod harvest index and seed and pod number per area indicating the importance of greater mobilization of photosyntates to pods and to seeds under rainfed conditions.
- Field evaluation of 97 RILs of the cross DOR 364 x BAT 477 under intermittent drought stress resulted in identification of two RILs BT 21138-68-1-1 and BT 21138-74-1-1 that were outstanding in adaptation to intermittent drought stress conditions. The superior performance of these lines under intermittent drought stress was associated with higher values of harvest index, pod partitioning index, stem biomass reduction, seed number per area and pod number per area

indicating the importance of greater mobilization of photosyntates to pods and seeds under rainfed conditions.

- Field evaluation of 121 RILs of the cross MD 23-24 x SEA 5 over 3 seasons resulted in identification of the lines MR 81 and MR 25 that were superior in adaptation to drought stress conditions. The superior performance of these lines was associated with higher vigor, higher values of pod harvest index, harvest index and seed number per area, highlighting the importance of the photosyntate mobilization to pods and seeds under intermittent drought stress.
- The response to inoculation with the strain *Rhizobium etli* CIAT 632 under drought stress was tested using 7 common bean genotypes. We found that Pinto Villa was better adapted to drought due to its ability to decrease stomatal conductance while Alubia cerrillos was more affected due to drought stress. Although there was no response to inoculation, the effect of terminal drought stress on nodulation was very marked on all 7 genotypes.

2.1.1.1 Evaluations of Mesoamerican lines segregating for drought resistance and tolerance to low soil P

Rationale: Abiotic stresses tend to be associated with marginal environments and seldom occur individually. Rather, co-occurrence may result in interactions and greater yield losses than when stresses occur singly. This is especially the case when drought and low soil fertility co-occur. It appears that nutrient deficiencies may limit root development and result in greater susceptibility to drought. It is therefore desirable to combine resistance or tolerance to drought and to low soil fertility, especially low soil P, which is the most common edaphic constraint of beans. Some progress had been made in this regard already, both in the small red class and in carioca type. In the genotypes reported here, we sought to obtain greater expression of multiple stress tolerance and in a greater number of genotypes.

Materials and methods: Double crosses of four parents were created involving drought resistant parents, especially those with small red grain, with lines that had been observed to perform well under fertility stress. Sources of low P tolerance included: SXB's 407, 409, 415, 418 (all derived from crosses for Brazil including carioca parents); small reds SER's 118 and 119; NCB 226 (black seeded); and BFB's 611 and 613 (from low P crosses). Other parents carried the *bc-3* gene for BCMNV and had also been selected under drought stress (RCB's 588, 589, 591, 592). F_2 populations were selected under drought in 2007 as $F_{1.2}$ families, and as $F_{1.3}$ families in Popayán. $F_{3.4}$ families were selected in Santander de Quilichao under inoculation with angular leaf spot and moderate fertility stress. The $F_{3.5}$ bulks were returned to the drought nursery in August, 2008 in two lattice designs: a 5 x 5 and a 6 x 6. Yield data under drought stress are reported here. Data on response to the NL-3 (necrotic) strain of BCMNV were obtained in the greenhouse.

Results and Discussion: Although most trials in the drought nursery in 2008 suffered only intermittent, moderate drought, these two trials were planted late and matured in September when days were sunny and drought stress was more reliable. These trials received an estimated 134 mm of water, from one furrow irrigation and 99 mm of rainfall. Thus, although stress was still moderate, it was more severe on these trials than in others in the main planting. Yields of checks were similar in the two trials: average yields of Tio Canela were 1463 kg ha^{-1}, and those of SER 16 were 1959 kg ha^{-1} (Tables 17 and 18). About 40% of the lines yielded significantly more than the Tio Canela check. Among lines that out yielded Tio Canela, two lines in Table 17 presented evidence of the *bc*-3 gene combined with drought resistance, and four lines in Table 18 appeared to be segregating this gene. This gene is especially important in Africa, where multiple stress tolerance is a high priority. These lines were planted under drought and low P stress in Darién, and individual plants were selected. These will be evaluated under drought stress in the upcoming season.

Collaborators: S. Beebe, M. Grajales, C. Cajiao, M. Castaño, A. Guerrero

Table 17. Yield under drought of 23 lines developed to combine drought resistance with low fertility tolerance.

	Cross code	Pedigree	COL	ALS	BCMNV	DTF	DTM	g/100s	kg ha^{-1}	kg ha^{-1} d^{-1}
SBCZ	16238-030	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-1P-MQ	rd	1	9N	32	63	28	2313	36.5
SBCZ	16238-017	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-3P-MQ	bl	3	5N	33	65	28	2118	32.6
SBCZ	16238-019	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-9P-MQ	rd	4	8N	33	64	26	2056	31.9
SBCZ	16238-024	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-7P-MQ	Cr	6	10_O	32	64	26	2038	31.8
		SER 16				32	60	21	2029	33.7
SBCZ	16261-004	(SER 48xNCB 226)F1 X (SER 119xRCB 234)F1/-MC-5P-MQ	rd	4	9N	32	64	25	2018	31.6
SBCZ	16238-003	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-2P-MQ	rd	5	10N	34	64	23	2001	31.3
SBCZ	16238-017	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-5P-MQ	bl	4	8N	33	65	26	1960	30.3
SBCZ	16284-006	(SER 97xNCB 226)F1 X BFB 611/-MC-7P-MQ	rd	4	8N	33	63	24	1947	30.8
SBCZ	16238-019	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-11P-MQ	rd	4	8N	32	64	24	1942	30.3
SBCZ	16236-066	(SER 89xRCB 234)F1 X (SXB 407xSER 118)F1/-MC-1P-MQ	rd	4	10N	33	63	26	1860	29.7
SBCZ	16274-081	(SER 119xNCB 226)F1 X (SER 113xRCB 590)F1/-MC-2P-MQ	rd	2	3N_ 6_O	35	64	24	1858	29.0
SBCZ	16238-003	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-1P-MQ	rd	5	7N	33	63	25	1835	29.0
SBCZ	16238-009	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-3P-MQ	rd	5	9N	33	65	27	1825	28.0
SBCZ	16279-034	(SXB 418xNCB 226)F1 X BFB 613/-MC-4P-MQ	pk	2	4N	35	62	21	1819	29.2
SBCZ	16261-025	(SER 48xNCB 226)F1 X (SER 119xRCB 234)F1/-MC-3P-MQ	rd	4	8N	33	63	23	1805	28.5
SBCZ	16261-004	(SER 48xNCB 226)F1 X (SER 119xRCB 234)F1/-MC-3P-MQ	rd	4	10N	33	66	25	1796	27.3
SBCZ	16238-019	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-7P-MQ	rd	4	8N	33	65	26	1790	27.7
SBCZ	16238-031	(SXB 415xSER 125)F1 X (SER 89xRCB 588)F1/-MC-7P-MQ	rd	3	9N	33	64	26	1698	26.6
SBCZ	16234-031	(SER 176xRCB 591)F1 X (SXB 407xSER 118)F1/-MC-11P-MQ	pk	4	5N	33	64	20	1649	25.8
SBCZ	16279-034	(SXB 418xNCB 226)F1 X BFB 613/-MC-5P-MQ	rd	5	7N	32	63	25	1627	25.9
SBCZ	16284-006	(SER 97xNCB 226)F1 X BFB 611/-MC-10P-MQ	rd	4	6N	33	62	22	1603	25.8
SBCZ	16236-004	(SER 89xRCB 234)F1 X (SXB 407xSER 118)F1/-MC-2P-MQ	rd	5	9N	33	62	25	1564	25.1
SCTZ	16268-25	(SER 118xBCB 587)F1 X (SXB 409xAQB 609)F1/-MC-1P-MQ	Cr Str	4	5N	38	67	23	1522	22.8
		TIO CANELA 75				38	65	19	1414	21.7
		LSD (0.05)				**1.2**	**1.8**	**1.5**	**394**	**12.1**

COL=Color; rd=red; bl=black; pk=pink; cr=cream; ALS= angular leaf spot (1-9 scale); BCMNV=bean common mosaic necrotic virus; N=necrotic reaction; 0=no symptoms; g/100s=grams per 100 seed.

Table 18. Yield under drought of 34 lines developed to combine drought resistance with low fertility tolerance.

	Code	Pedigree	COL	ALS	BCMNV	DTF	DTM	g/100s	kg ha^{-1}	kg ha^{-1} d^{-1}
SBCZ	16257-33	(SER 48xRCB 234)F1 X (SER 118xNCB 226)F1/-MC-2P-MQ	rd	4	7N_ 2_O	33	65	27	2024	31.1
SBCZ	16245-01	(SER 76xRCB 589)F1 X (SXB 407xSER 119)F1/-MC-4P-MQ	rd	3	9N	33	64	27	1992	31.0
SBCZ	16257-33	(SER 48xRCB 234)F1 X (SER 118xNCB 226)F1/-MC-1P-MQ	rd	5	6N	33	65	28	1984	30.5
SBCF	16231-006	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-14P-MQ	rd	5	8N	35	64	30	1967	30.6
SBCZ	16257-21	(SER 48xRCB 234)F1 X (SER 118xNCB 226)F1/-MC-9P-MQ	rd	3	7N	34	63	29	1928	30.7
SBCZ	16253-006	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-5P-MQ	rd	5	4N_ 3_O	34	65	24	1908	29.3
		SER 16				33	63	22	1889	30.0
SBCZ	16234-031	(SER 176xRCB 591)F1 X (SXB 407xSER 118)F1/-MC-2P-MQ	rd	5	6N_ 2_O	33	66	28	1887	28.6
SBCZ	16253-008	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-6P-MQ	rd	3	6N	33	65	31	1859	28.6
SCFZ	16265-002	(SER 118xRCB 590)F1 X (SMR 3xMIB 499)F1/-MC-15P-MQ	rd	4	5N_ 3_O	33	64	31	1856	28.9
SBCZ	16245-01	(SER 76xRCB 589)F1 X (SXB 407xSER 119)F1/-MC-3P-MQ	rd	3	7N	34	64	28	1836	28.5
SBCF	16231-005	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-1P-MQ	rd	5	6N	35	65	29	1823	27.9
SBCF	16231-006	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-4P-MQ	rd	3	9N	33	65	26	1818	27.9
SBCF	16231-002	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-11P-MQ	rd	6	9N	34	66	25	1802	27.3
SBCZ	16234-004	(SER 176xRCB 591)F1 X (SXB 407xSER 118)F1/-MC-1P-MQ	Sd	5	9_O	35	65	28	1785	27.3
SBCZ	16253-008	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-2P-MQ	rd	3	8N	34	64	27	1785	27.9
SBCF	16231-002	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-8P-MQ	rd	4	9N	34	64	26	1764	27.5
SBCZ	16234-031	(SER 176xRCB 591)F1 X (SXB 407xSER 118)F1/-MC-12P-MQ	rd	4	7N	33	64	24	1749	27.3
SBCZ	16253-040	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-2P-MQ	rd	5	9N	34	65	27	1742	26.6
SBCZ	16253-014	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-1P-MQ	rd	4	6N	34	66	26	1715	26.1
SBCF	16231-006	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-9P-MQ	rd	6	8N	35	64	27	1714	26.7
SBCZ	16257-21	(SER 48xRCB 234)F1 X (SER 118xNCB 226)F1/-MC-5P-MQ	rd	4	6_O	34	64	32	1690	26.4
SBCZ	16245-01	(SER 76xRCB 589)F1 X (SXB 407xSER 119)F1/-MC-5P-MQ	rd	3	8N	34	65	28	1677	25.9
SBCF	16231-005	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-2P-MQ	Sd	4	8N	36	67	24	1651	24.8
SBCZ	16253-008	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-4P-MQ	rd	3	7N	34	65	30	1650	25.4
SBCZ	16253-040	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-23P-MQ	rd	4	7N	35	65	24	1641	25.1
SBCZ	16253-040	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-12P-MQ	rd	4	10N	34	66	27	1636	24.7
SBCZ	16253-006	(SER 102xRCB 592)F1 X (SXB 415xSER 119)F1/-MC-3P-MQ	rd	4	1N_ 5_O	32	64	27	1614	25.1
SBCF	16231-015	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-5P-MQ	rd	3	8N	35	65	26	1593	24.6
SCFZ	16265-002	(SER 118xRCB 590)F1 X (SMR 3xMIB 499)F1/-MC-13P-MQ	rd	4	2N_ 6_O	35	65	31	1581	24.2
SBCF	16231-002	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-21P-MQ	rd	5	9N	34	65	24	1532	23.6
SBCF	16231-005	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-6P-MQ	rd	5	3N_ 2_O	35	66	27	1523	23.2
SBCZ	16257-21	(SER 48xRCB 234)F1 X (SER 118xNCB 226)F1/-MC-12P-MQ	rd	4	9_O	34	64	32	1515	23.5
		TIO CANELA 75				36	68	20	1512	22.3
SBCZ	16257-21	(SER 48xRCB 234)F1 X (SER 118xNCB 226)F1/-MC-4P-MQ	rd	5	1N_ 6_O	32	64	30	1505	23.5
SBCF	16231-005	(SER 155xRCB 591)F1 X (SER 118xSXB 409)F1/-MC-4P-MQ	rd	5	8N	35	67	27	1500	22.4
		LSD (0.05)				**1.0**	**1.4**	**2.0**	**332**	**5.0**

COL=Color; rd=red; Sd=rojo de seda light red; ALS= angular leaf spot (1-9 scale); BCMNV=bean common mosaic necrotic virus; N=necrotic reaction; 0=no symptoms; g/100s=grams per 100 seed.

2.1.1.2 Evaluations of Mesoamerican lines segregating for drought resistance and *bc*-3 gene

Rationale: At the outset of the Bean Program in the 1970's, BCMV was highlighted as a priority, and in Latin America the dominant *I* gene was amply deployed for this problem. Over time it has become necessary to broaden the genetic base of the BCMV resistance with the *bc-3* gene, on the one hand to avoid certain problems of genetic linkage to dark grain color, and on the other hand to address the threat of necrotic strains of BCMNV in Africa and elsewhere. As drought resistance has become one of the central priorities of the bean breeding programs, we have sought to develop a gene pool with drought resistance and key genes including the *bc*-3. The present report informs on the performance of families derived from populations segregating for drought resistance and *bc*-3 gene.

Materials and Methods: Simple crosses were created between elite drought resistant lines with the *I* gene and sources of *bc*-3 gene, and well as crosses among the elite lines. Individual plants were selected from populations of simple crosses in F_3 generation, seed was bulked in the F_4 generation, and trials were planted in the drought season as F_5 families in two 6 x 6 lattices. Reaction to the NL-3 strain of BCMNV was obtained in greenhouse inoculations.

Results and Discussion: These trials received an estimated 170 mm of water (see section 1 above) but soil structure was not favorable. Root development may have been limited, contributing to greater stress. About half of the lines yielded significantly more than the Tio Canela check, which averaged 1279 kg ha^{-1} in these two trials (Tables 19 and 20). Only two of the families with superior drought yields were homozygous for the *bc-3* gene (as evidenced by the reaction of "0" in Tables 19 and 20), but at least 12 families showed evidence of segregation of *bc-3*, requiring additional selection to purify lines for *bc*-3. Such lines will augment a growing number of such genotypes that are creating a gene pool based on drought and in which the *bc-3* gene must become the basis for BCMNV resistance.

Collaborators: S. Beebe, M. Grajales, C. Cajiao, M. Castaño, A. Guerrero

Table 19. Yield under drought of 33 families derived from populations segregating for drought resistance and *bc-3* resistance to BCMNV.

	Code	Pedigree	COL	BCMNV	DTF	DTM	g/100s	kg ha^{-1}	kg ha^{-1} d^{-1}
SC	16040	SER 48xRCB 593/-MC-22C-MC	rd	9N	35	64	28	2167	33.9
SC	16045	SER 118xNCB 226/-MC-14C-MC	rd	11N	33	63	24	2062	32.7
SC	16050	SER 113xRCB 590/-MC-1C-MC	rd	6N_ 2O	34	65	25	2022	31.4
SC	16040	SER 48xRCB 593/-MC-7C-MC	rd	8N_ 1O	33	63	27	2002	31.8
SC	16050	SER 113xRCB 590/-MC-11C-MC	rd	8N	34	65	27	1957	29.9
SC	16041	SER 48xNCB 226/-MC-16C-MC	rd	7N_ 2O	37	67	25	1947	28.9
SC	16040	SER 48xRCB 593/-MC-8C-MC	rd	8N	34	65	25	1911	29.3
SC	16041	SER 48xNCB 226/-MC-1C-MC	rd	6N_ 3O	33	62	23	1908	30.7
SC	16039	SER 48xRCB 234/-MC-4C-MC	rd	1N_ 6O	32	61	26	1883	30.8
SC	16040	SER 48xRCB 593/-MC-20C-MC	rd	7N_ 3O	35	64	26	1877	29.6
SC	16040	SER 48xRCB 593/-MC-23C-MC	rd	7N_ 1O	34	66	28	1862	28.4
SC	16045	SER 118xNCB 226/-MC-15C-MC	rd	8N	35	68	27	1860	27.5
SC	16045	SER 118xNCB 226/-MC-20C-MC	rd	10N	41	70	26	1859	26.7
SC	16040	SER 48xRCB 593/-MC-4C-MC	rd	7N_ 3O	33	63	25	1856	29.6

Table 19. cont'd.

	Code	Pedigree	COL	BCMNV	DTF	DTM	g/100s	kg ha^{-1}	kg ha^{-1} d^{-1}
SC	16040	SER 48xRCB 593/-MC-33C-MC	rd	5N_ 3O	33	64	26	1848	28.9
SC	16047	SER 119xNCB 226/-MC-9C-MC	rd	10N	33	63	21	1836	29.0
SC	16039	SER 48xRCB 234/-MC-14C-MC	rd	6_O	33	64	27	1832	28.5
Test	1	SER 16	rd		32	61	21	1812	29.6
SC	16045	SER 118xNCB 226/-MC-4C-MC	rd	10_O	33	66	24	1772	27.1
SC	16039	SER 48xRCB 234/-MC-16C-MC	rd	2N_ 1M_ 7_O	33	62	24	1730	27.7
SC	16045	SER 118xNCB 226/-MC-8C-MC	rd	9N	35	63	23	1730	27.2
SC	16040	SER 48xRCB 593/-MC-28C-MC	rd	8N_ 1_O	33	62	28	1693	27.1
SC	16041	SER 48xNCB 226/-MC-13C-MC	rd	7N	34	67	26	1674	25.0
SC	16047	SER 119xNCB 226/-MC-7C-MC	rd	8N	34	65	24	1665	25.8
SC	16040	SER 48xRCB 593/-MC-19C-MC	rd	6N_ 2_O	33	63	27	1660	26.5
SC	16040	SER 48xRCB 593/-MC-25C-MC	rd	7N_ 1_O	34	63	28	1659	26.3
SC	16040	SER 48xRCB 593/-MC-3C-MC	rd	8_O	34	64	25	1659	25.9
SC	16041	SER 48xNCB 226/-MC-12C-MC	rd	6N_ 2_O	33	64	27	1657	25.8
SC	16050	SER 113xRCB 590/-MC-4C-MC	rd	6N	33	64	25	1656	25.9
SC	16045	SER 118xNCB 226/-MC-5C-MC	rd	10_O	38	70	22	1549	22.0
SC	16050	SER 113xRCB 590/-MC-6C-MC	rd	11N	41	70	25	1541	22.1
SC	16040	SER 48xRCB 593/-MC-12C-MC	rd	1N_ 9_O	33	63	27	1531	24.2
SC	16040	SER 48xRCB 593/-MC-5C-MC	rd	10_O	33	62	26	1511	24.3
Test	3	DOR 390	bl		40	70	18	1480	21.1
Test	2	TIO CANELA 75	rd		39	70	18	1471	21.1
SC	16045	SER 118xNCB 226/-MC-17C-MC	rd	10_O	39	65	24	1417	21.7
		LSD (0.05)			**1.0**	**1.4**	**2.0**	**332**	**5.0**

COL=Color; rd=red; bl=black; BCMNV=bean common mosaic necrotic virus; N=necrotic reaction; 0=no symptoms; g/100s=grams per 100 seed.

Table 20. Yield under drought of 34 families derived from populations segregating for drought resistance and *bc*-3 resistance to BCMNV.

	Code	Pedigree	COL	BCMNV	DTF	DTM	g/100s	kg ha^{-1}	kg ha^{-1} d^{-1}
SD	16012	SER 101xSEN 53/-MC-4C-MC	bl	N	34	65	22	1922	29.4
SD	16006	SXB 403xSEN 53/-MC-4C-MC	bl	N	33	61	23	1815	29.6
SCFZ	16073	RCB 584xMIB 487/-MC-7C-MC	bl	10_O	35	62	24	1760	28.6
SC	16047	SER 119xNCB 226/-MC-2C-MC	bl	11N	34	64	23	1683	26.1
SC	16047	SER 119xNCB 226/-MC-6C-MC	bl	11N	33	63	23	1656	26.3
SC	16054	SER 42xRCB 593/-MC-32C-MC	rd	10_O	33	61	25	1642	26.8
SD	15597	SER 119xSEN 46/-MC-12C-MC	bl	N	33	64	23	1627	25.6
SC	16041	SER 48xNCB 226/-MC-3C-MC	bl	2N_ 8_O	33	63	28	1619	25.7
SC	16054	SER 42xRCB 593/-MC-16C-MC	rd	10N	33	64	25	1603	24.9
SC	16054	SER 42xRCB 593/-MC-22C-MC	rd	8N	36	67	25	1572	23.4
SD	15597	SER 119xSEN 46/-MC-8C-MC	bl	N	33	62	22	1562	25.3
SCFZ	16073	RCB 584xMIB 487/-MC-5C-MC	bl	8N_ 2_O	34	64	24	1557	24.3
SD	16011	SER 119xSEN 46/-MC-4C-MC	bl	N	34	64	23	1543	24.1
SC	16054	SER 42xRCB 593/-MC-29C-MC	rd	4N_ 4_O	33	63	24	1528	24.1
SBCZ	15999	NCB 226xRCB 588/-MC-2C-MC	bl	5_O	34	68	27	1517	22.1
SD	16011	SER 119xSEN 46/-MC-1C-MC	bl	N	35	68	23	1516	22.6
SC	16054	SER 42xRCB 593/-MC-2C-MC	rd	1N_ 9_O	34	63	26	1500	24.1
SC	16050	SER 113xRCB 590/-MC-18C-MC	rd	9N	34	65	26	1499	23.1
SC	16054	SER 42xRCB 593/-MC-17C-MC	rd	10_O	34	65	24	1488	22.9
SC	16054	SER 42xRCB 593/-MC-7C-MC	rd	1N_ 9_O	33	63	25	1487	23.4
SC	16051	SER 97xNCB 226/-MC-19C-MC	bl	10N	33	62	26	1482	23.8
SBCZ	15999	NCB 226xRCB 588/-MC-8C-MC	bl	5_O	34	65	25	1468	22.6
SC	16054	SER 42xRCB 593/-MC-27C-MC	rd	5N_ 5_O	33	65	26	1460	22.4
SD	15597	SER 119xSEN 46/-MC-14C-MC	rd	N	34	66	23	1411	21.4
SD	15597	SER 119xSEN 46/-MC-10C-MC	bl	N	33	63	22	1400	22.3
SD	15597	SER 119xSEN 46/-MC-1C-MC	rd	N	36	66	23	1400	21.3
SD	15597	SER 119xSEN 46/-MC-6C-MC	bl	N	34	63	24	1364	21.6
SD	15597	SER 119xSEN 46/-MC-13C-MC	rd	N	33	63	23	1345	21.3
SC	16054	SER 42xRCB 593/-MC-28C-MC	rd	9_O	37	68	23	1327	19.7
SD	15597	SER 119xSEN 46/-MC-11C-MC	bl	N	33	62	24	1318	21.2
SC	16054	SER 42xRCB 593/-MC-9C-MC	rd	9N	33	63	25	1310	20.7
SC	16054	SER 42xRCB 593/-MC-1C-MC	rd	4N_ 3_O	33	65	28	1306	20.2
Test	1	SER 16	rd		32	63	21	1287	20.4
SC	16045	SER 118xNCB 226/-MC-34C-MC	bl	10_O	37	68	22	1237	18.1
SC	16054	SER 42xRCB 593/-MC-11C-MC	rd	8N	37	65	23	1191	18.3
Test	2	TIO CANELA 75	rd		39	68	19	1187	17.6
		LSD (0.05)			**1.0**	**1.4**	**2.0**	**332**	**5.0**

COL=Color; rd=red; bl=black; BCMNV=bean common mosaic necrotic virus; N=necrotic reaction; 0=no symptoms; g/100s=grams per 100 seed.

2.1.1.3 Evaluations of Andean lines for drought resistance and for yield potential under irrigation

Rationale: In 2007 we reported on the yield of Andean lines under rainfed conditions. In that year different trials performed quite differently according to their position in the field, although several new lines were promising. To have more confidence in the drought reaction of these lines, the trials were repeated in 2008 in the drought season. In 2008 the same lines were also planted under irrigated conditions to establish their yield potential in a favorable environment in Palmira.

Materials and Methods: Yield trials were established in Palmira (1000 masl; 26°C average temperature) as described in previous years, in lattice designs of 4 x 4, 5 x 5, or 6 x 6 in three replications. Two row plots 3.75 m long were planted in July under rainfed conditions to induce drought stress. Irrigation was applied twice up to 20 days after planting, after which all additional moisture resulted from rainfall. An irrigated treatment was established with the same design in which plots were furrow irrigated as needed. Pests were controlled as needed.

Results and Discussion: Excessive rain prior to planting made field preparation extremely difficult in the 2008 drought season, and the soil structure in the drought treatement was especially poor. As a result plant development was sub-optimal, and root penetration might have been limited. As with other trials in this field, the crop received an estimated 170 mm of water during the crop cycle, but in this field the crop appeared to suffer severe drought stress. Compared to the irrigated treatment, yield reduction averaged 48%. Furthermore, weeds were plowed down only shortly before planting, and the fresh organic matter generated a severe attack of *Sclerotium rolfsii*.

The local check 'Calima' fared badly in these conditions and was the poorest yielding in every trial where it appeared. In spite of agronomic problems, yields were quite acceptable in several lines, approaching 1.5 MT or more in some materials (Tables 21 to 25). In every trial except for that of the red-mottled types, at least one line significantly out yielded the drought resistant check, ICA Quimbaya. Some lines performed well in both years, for example: red seeded SAB 680; white seeded SAB 711; cream striped SAB's 627, 684, 686, and 702; and red mottled SAB 641.

Several drought resistant lines also yielded well in irrigated conditions. For example, red-seeded SAB's 623 and 671 yielded very well in drought, and comparably to ICA Quimbaya with irrigation, but were four days earlier to mature (Table 21). Cream-striped SAB's 685 and 686 yielded well in both drought and irrigation, and were 3-5 days earlier to mature than the checks (Table 24). However, in general the yield advantage in relation to checks was narrower in the red mottled class than in other grain types in both 2007 and 2008.

These results serve to confirm the advantage under rainfed conditions of the selected Andean genotypes. Furthermore, when compared to the results under rainfed but favorable conditions in Darién (section 2.1.1.6) and irrigated conditions in Palmira (this section), in which yields of these lines were superior to checks, this suggests that selection for drought resistance has increased yield potential. This is the same pattern that has been observed in Mesoamerican beans. However, in determinate Andean beans it is especially significant, since yield improvement in these types has always been a particular challenge. Physiological analysis will serve to determine if the drought resistant Andean types also present improved remobilization to grain, as in the case of the Mesoamerican drought selected lines. It is important to note that the sources of drought resistance included in these Andean lines, SAB's 258 and 259, have Mesoamerican genes derived from race Durango which has served as drought resistance source in much breeding work.

Collaborators: S. Beebe, I. Rao, M. Grajales, C. Cajiao, A. Guerrero

Table 21. Yield of selected red-seeded Andean lines under rainfed and irrigated conditions in Palmira, July-September 2008, and comparison to rainfed yield in 2007.

			Drought					Irrigated	
			DTM	g 100s^{-1}	kg ha^{-1}	kg ha^{-1} d^{-1}	kg ha^{-1} (2007)	kg ha^{-1}	DTM
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-34C-MC	SAB 680	60	36	1651	27,6	1571	2138	63
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-27C-MC	SAB 623	60	33	1501	25,0	1476	2631	63
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-5C-MC	SAB 671	60	38	1450	24,2	1576	2568	63
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-20C-MC	SAB 677	60	36	1322	22,1	1465	2533	62
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-8C-MC	SAB 672	61	34	1295	21,5	1339	2605	65
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-31C-MC	SAB 678	59	35	1265	21,6	1536	2592	62
15455-14	(ABA 58 x ICA QUIMBAYA)F1xSAB 258-MC-28C-MC-MC-32C-MC	SAB 679	61	38	1243	20,4	1790	2696	63
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-4C-MC	SAB 670	61	30	1234	20,4	1473	2756	63
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-4C-MC	SAB 669	59	37	1213	20,4	1176	2298	64
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-12C-MC	SAB 674	60	33	1200	20,0	1403	2275	63
	ICA QUIMBAYA		70	39	1183	16,7	1178	2606	67
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-7C-MC	SAB 621	59	36	1135	19,3	1528	2684	62
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-17C-MC	SAB 732	59	31	1121	18,9	1290	2383	63
15453-6	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-10C-MC-MC-15C-MC	SAB 667	61	42	1109	18,3	1340	1972	63
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-15C-MC	SAB 622	61	31	1084	17,6	1548	2824	65
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-3C-MC	SAB 668	61	31	1081	17,8	1149	2294	63
	COS 16		64	30	1079	16,9	973	2280	68
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-9C-MC	SAB 673	58	31	1075	18,5	1371	2268	62
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-19C-MC	SAB 676	59	36	1067	18,2	1315	2412	62
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-17C-MC	SAB 675	61	35	1027	17,0	1635	2376	62
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-3C-MC	SAB 620	61	32	1022	16,9	1199	2430	63
15453-6	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-10C-MC-MC-6C-MC	SAB 666	60	34	1016	16,9	1171	2170	63
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-14C-MC	SAB 731	59	29	923	15,5	1031	2411	63
15453-6	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-10C-MC-MC-4C-MC	SAB 665	60	33	854	14,3	1242	1816	64
15455-14	CALIMA		67	43	667	9,9	1325	1394	63
	LSD (0.05)		**3.1**	**3.4**	**411**	**6.7**		**561**	**1.8**

Table 22. Yield of selected white-seeded Andean lines under rainfed conditions in Palmira, July-September 2008, and comparison to rainfed yield in 2007.

			Drought					Irrigated	
			DTM	g 100s^{-1}	kg ha^{-1}	kg ha^{-1} d^{-1}	kg ha^{-1} (2007)	kg ha^{-1}	DTM
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-13C-MC	SAB 737	63	32	1446	23,0	1368	2496	69
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-16C-MC	SAB 711	61	27	1439	23,8	1577	3029	68
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-4C-MC	SAB 708	61	32	1370	22,6	1546	2268	68
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-17C-MC	SAB 712	60	33	1363	23,0	1546	2611	69
15453-24	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-21C-MC-MC-15C-MC	SAB 703	60	34	1307	21,8	1129	2101	63
15453-24	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-21C-MC-MC-18C-MC	SAB 704	60	31	1279	21,1	1292	2146	64
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-32C-MC-MC-24C-MC	SAB 718	59	31	1274	21,3	1267	2516	64
15455-2	(ABA 58xICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-9C-MC	SAB 709	61	30	1273	20,9	1593	2805	67
15453-24	(ABA 36xICA QUIMBAYA) x SAB 258-MC-21C-MC-MC-24C-MC	SAB 705	60	37	1243	20,8	1303	1815	62
15455-2	(ABA 58xICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-14C-MC	SAB 738	63	25	1215	19,4	1384	2296	65
	ABA 36		65	33	1210	18,6	1240	2491	71
15455-2	(ABA 58 x ICA QUIMBAYA) F1 x SAB 258-MC-32C-MC-MC-3C-MC	SAB 714	59	30	1209	20,5	1138	21231	63
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-32C-MC-MC-26C-MC	SAB 719	59	31	1127	19,1	1300	2767	63
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-12C-MC-MC-6C-MC	SAB 736	60	27	1126	18,8	1415	2754	62
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-12C-MC-MC-14C-MC	SAB 707	59	27	1115	19,1	1526	2507	61
15453-24	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-21C-MC-MC-19C-MC	SAB 734	60	35	1095	18,5	1121	2188	63
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-32C-MC-MC-21C-MC	SAB 716	60	31	1051	17,6	1214	2311	62
	ICA QUIMBAYA		64	38	1037	16,2	1298	2489	66
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-5C-MC	SAB 634	61	27	1017	16,5	1199	2504	64
15453-24	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-21C-MC-MC-26C-MC	SAB 706	59	36	986	16,7	1239	2270	63
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-12C-MC	SAB 710	62	28	973	15,7	1654	2758	67
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-32C-MC-MC-15C-MC	SAB 715	59	29	950	16,3	1115	2339	63
15453-24	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-21C-MC-MC-30C-MC	SAB 735	60	34	934	15,5	1416	1958	63
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-32C-MC-MC-22C-MC	SAB 717	60	30	921	15,2	1177	2324	63
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-1C-MC	SAB 713	63	29	854	13,4	1519	2689	70
	LSD (0.05)		**1.8**	**3.0**	**388**	**6.3**		**305**	**2.8**

Table 23. Yield of selected red-mottled Andean lines under rainfed conditions in Palmira, July-September 2008, and comparison to rainfed yield in 2007.

			DTF	DTM	g 100s^{-1}	kg ha^{-1}	kg ha^{-1} d^{-1}	kg ha^{-1} (2007)
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-12C-MC	SAB 651	31	59	34	1157	19,9	2012
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-1C-MC-MC-4C-MC	SAB 641	32	61	33	1009	16,3	2135
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-7C-MC	SAB 643	31	59	28	952	16,0	1670
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-19C-MC	SAB 652	31	59	34	948	16,0	1973
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-15C-MC-MC-3C-MC	SAB 618	30	60	31	926	15,5	2180
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-6C-MC	SAB 644	31	59	29	920	15,7	1716
	ICA QUIMBAYA		33	64	37	898	14,1	2318
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258/-MC-2C-MC-MC-1C-MC	SAB 664	30	59	34	881	15,1	1723
	COS 16		33	64	29	878	13,7	1777
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-4C-MC-MC-4C-MC	SAB 653	30	59	31	857	14,7	1748
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-2C-MC	SAB 646	30	59	31	855	14,3	2203
15459-10	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-10C-MC	SAB 619	32	61	35	830	13,7	1595
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-15C-MC-MC-16C-MC	SAB 662	30	60	37	805	13,6	1709
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-8C-MC-MC-14C-MC	SAB 659	31	61	39	789	13,0	2358
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-15C-MC-MC-17C-MC	SAB 663	31	60	32	748	12,5	1802
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-8C-MC-MC-4C-MC	SAB 617	31	63	37	724	11,6	1838
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-33C-MC-MC-4C-MC	SAB 616	30	58	28	718	12,4	2104
15455-2	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-11C-MC-MC-1C-MC	SAB 642	31	59	26	706	12,1	1935
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-10C-MC	SAB 649	31	58	34	697	12,0	2040
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-8C-MC-MC-11C-MC	SAB 658	31	62	37	682	10,9	2054
15453-8	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-1C-MC-MC-4C-MC	SAB 638	32	61	35	682	11,1	1993
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-8C-MC-MC-6C-MC	SAB 657	32	61	37	680	11,3	2131
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-3C-MC	SAB 647	31	59	29	651	11,0	1929
15453-6	(ABA 36xICA QUIMBAYA) x SAB 258-MC-7C-MC-MC-6C-MC	SAB 636	30	60	37	651	11,0	1965
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-15C-MC-MC-6C-MC	SAB 661	30	59	37	645	10,9	1656
15453-6	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-7C-MC-MC-14C-MC	SAB 637	32	61	37	633	10,3	1859
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-8C-MC-MC-19C-MC	SAB 660	31	63	36	615	9,9	1961
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-4C-MC	SAB 648	31	60	34	604	10,0	1834
15453-8	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-7C-MC-MC-15C-MC	SAB 640	31	61	37	602	9,8	2127
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-28C-MC-MC-7C-MC	SAB 645	31	59	30	573	9,5	2152
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-5C-MC	SAB 654	30	58	31	566	9,7	1442
15455-14	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-17C-MC-MC-7C-MC	SAB 655	32	59	29	555	9,4	1399
15453-8	(ABA 36 x ICA QUIMBAYA) x SAB 258-MC-7C-MC-MC-4C-MC	SAB 639	32	62	35	554	8,9	1909
15459-4	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-8C-MC-MC-3C-MC	SAB 656	32	63	39	540	8,6	1902
15455-5	(ABA 58 x ICA QUIMBAYA) x SAB 258-MC-36C-MC-MC-11C-MC	SAB 650	32	61	34	528	8,7	2272
	CALIMA		33	63	39	436	7,0	1897
	LSD (0.05)		**1.3**	**1.9**	**2.6**	**341**	**5.7**	

Table 24. Yield of selected cream-striped Andean lines under rainfed amd irrigated conditions in Palmira, July-September 2008, and comparison to rainfed yield in 2007.

			Drought					Irrigated	
			DTM	g 100s^{-1}	kg ha^{-1}	kg ha^{-1} d^{-1}	kg ha^{-1} (2007)	kg ha^{-1}	DTM
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-13C-MC-MC-19C-MC	SAB 684	61	31	1326	21.9	2356	2427	63
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-36C-MC	SAB 689	61	33	1283	21.2	1708	2657	64
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-26C-MC	SAB 686	60	33	1260	21.2	2155	2900	65
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-22C-MC	SAB 627	60	35	1218	20.3	2123	2848	64
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-21C-MC	SAB 685	60	34	1212	20.2	2093	3303	66
15460-7	(COS 16 x ICA QUIMBAYA) x SAB 259-MC-16C-MC-MC-30C-MC	SAB 702	61	32	1206	19.6	2124	2349	66
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-4C-MC	SAB 628	60	34	1197	20.1	2037	2705	65
15459-19	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -11C-MC-MC-4C-MC	SAB 697	61	34	1175	19.5	1467	2432	63
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-11C-MC	SAB 626	61	31	1159	19.1	2387	2760	65
15460-7	(COS 16 x ICA QUIMBAYA) x SAB 259-MC -16C-MC-MC-28C-MC	SAB 701	61	33	1152	18.8	1719	3136	67
15454-2	(ABA 36 x ICA QUIMBAYA) x SAB 259-MC-8C-MC-MC-8C-MC	SAB 624	62	36	1146	18.4	1858	2957	67
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-31C-MC	SAB 733	60	32	1142	19.1	1448	2892	63
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-4C-MC	SAB 682	60	33	1126	18.7	2032	2547	64
15454-2	(ABA 36xICA QUIMBAYA)F1xSAB 259/-MC-8C-MC-MC-2C-MC	SAB 681	61	38	1125	18.2	2009	2782	68
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-7C-MC	SAB 625	61	31	1120	18.5	1757	2637	63
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-25C-MC	SAB 630	61	33	1105	18.3	2061	2422	65
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-26C-MC	SAB 696	61	35	1081	17.8	2013	2568	65
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-32C-MC	SAB 687	60	30	1061	17.7	2005	3283	64
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-35C-MC	SAB 688	61	30	1059	17.6	1663	3177	64
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -13C-MC-MC-8C-MC	SAB 683	60	32	1051	17.5	2111	2934	65
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-3C-MC	SAB 690	60	34	1014	16.8	2073	2979	66
15459-19	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -11C-MC-MC-13C-MC	SAB 633	59	33	1012	17.4	1546	2436	63
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-7C-MC	SAB 692	61	35	1007	16.7	2382	2860	64
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-29C-MC	SAB 631	61	33	1002	16.3	2327	2626	66
CALIMA	CALIMA		63	37	974	15.4	1718	1549	68
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-6C-MC	SAB 691	59	33	962	16.0	2460	3114	64
	ICA QUIMBAYA		64	40	962	15.1	2131	2217	70
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-23C-MC	SAB 695	62	30	953	15.5	1776	2507	65
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-9C-MC	SAB 693	61	34	915	15.0	2297	2395	66
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-13C-MC	SAB 629	60	33	869	14.4	2537	2963	65
15459-19	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -11C-MC-MC-7C-MC	SAB 698	59	32	858	14.3	1672	2114	62
	COS 16		63	29	851	13.5	1742	2418	69
15459-19	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -11C-MC-MC-3C-MC	SAB 632	59	33	838	14.2	1404	2105	62
15459-19	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -11C-MC-MC-12C-MC	SAB 700	58	34	832	14.3	1620	1525	62
15459-19	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -11C-MC-MC-8C-MC	SAB 699	58	31	804	14.0	1400	1755	62
15459-2	(COS 16 x ICA QUIMBAYA) x SAB 258-MC -19C-MC-MC-21C-MC	SAB 694	60	35	791	13.1	2337	2480	63
	LSD (0.05)		**1.8**	**2.9**	**349**	**5.9**		**775**	**1.6**

Table 25. Yield of selected Andean lines of several colors under rainfed conditions in Palmira, July-September 2008, and comparison to rainfed yield in 2007.

			DTF	DTM	g 100s^{-1}	kg ha^{-1}	kg ha^{-1} d^{-1}	kg ha^{-1} (2007)
15460-7	(COS 16 x ICA QUIMBAYA) x SAB 259-MC-16C-MC-MC-34C-MC	SAB 730	31	61	36	1060	17,4	1017
15460-7	(COS 16 x ICA QUIMBAYA) x SAB 259-MC-16C-MC-MC-33C-MC	SAB 729	32	62	35	974	15,9	1110
	COS 16		32	62	29	973	15,7	942
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-2C-MC-MC-12C-MC	SAB 721	32	60	34	944	15,8	1125
	SAB 560		32	62	33	937	15,2	1610
15460-7	(COS 16 x ICA QUIMBAYA) x SAB 259-MC-16C-MC-MC-19C-MC	SAB 728	32	62	37	909	14,8	973
15456-4	(ABA 58 x ICA QUIMBAYA) x SAB 259-MC-7C-MC-MC-9C-MC	SAB 727	33	62	29	885	14,3	1183
15456-4	(ABA 58 x ICA QUIMBAYA) x SAB 259-MC-7C-MC-MC-4C-MC	SAB 726	33	62	31	827	13,2	1293
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-2C-MC-MC-2C-MC	SAB 720	31	59	35	800	13,6	1133
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-5C-MC-MC-6C-MC	SAB 724	30	59	36	762	12,9	1065
	ICA QUIMBAYA		33	69	37	751	10,8	1227
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-5C-MC-MC-7C-MC	SAB 725	31	60	36	713	11,9	1007
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-5C-MC-MC-4C-MC	SAB 739	31	60	37	695	11,6	1137
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-5C-MC-MC-5C-MC	SAB 723	31	59	35	661	11,3	977
15459-11	(COS 16 x ICA QUIMBAYA) x SAB 258-MC-5C-MC-MC-1C-MC	SAB 722	31	60	33	595	9,9	947
	CALIMA		33	64	40	559	8,8	1004
	LSD (0.05)		**1.4**	**2.7**	**2.6**	**249**	**4.0**	

2.1.1.4 Development of drought tolerant Andean beans from inter and intra-genepool crosses

Rationale: Common bean suffers from drought stress in a large part of Eastern and Southern Africa where Andean large-seeded beans are the preferred types among the majority of the countries and populations represented (Wortman et al., 1998). Furthermore, although common bean is often grown on marginal soils in drought-prone areas where yields are low, they are still the second source of protein and third source of calories in the African highlands (Asfaw et al., 2007). Therefore breeding for drought tolerance in Andean beans is a priority from the perspective of both agricultural productivity and food security. With this in mind we have developed a series of advanced lines from inter- and intra-genepool crosses using 10 sources of drought tolerance and 5 commercial cultivars from the region. These lines have been called Drought Andean Bean (DAB) lines and are now being tested in a yield trial under drought stress at CIAT.

Materials and Methods: A North Carolina design II was used to generate 49 experimental F_2 populations from 5 large seeded varieties popular in Southern Africa and parts of Eastern Africa (Red Canadian Wonder, CAL143, SUG131, PAN147, Natal Sugar) and drought tolerant sources including 5 males of Andean origin (RAA21, SEQ1003, SAB259, ICA Quimbaya [=AFR 298], ICA Palmar) and 5 males of Mesoamerican origin (SER8, SER16, SER22, SEC16, SEQ11) as described in further detail in Makunde et al. (2007). One cross between Red Canadian Wonder and SER22 failed due to dwarf lethality but all other F_1s produced F_2 seed in Cali, Colombia in September 2005. Generations were advanced at two sites in Colombia, alternating between dry season plantings in Palmira and Darién, and pedigree selection was used to make selections. Final single plant selections were made in the F_5 generation and two sets of lines were made: one derived from inter-genepool crosses (AxM) and one from intra-genepool crosses (AxA). The $F_{5:6}$ lines were then planted for agronomic evaluation in Darién (Andic Dystrudept, pH = 5.5) in the case of the AxA lines and Palmira (Aquic Haplustoll, pH 7.0) in the case of the AxM lines in the June – September 2008 dry season under rainfed conditions, where the experiments consisted in 1354 and 492 lines respectively and these were interspersed with the parents as drought control genotypes. Rainfall during the season in Palmira was 163 mm with minimum temperatures of 17 to 25 °C and maximum temperatures of 25 to 33 °C; while in Darién, rainfall during the season was 280 mm, with average temperatures that fluctuated between 13 and 26°C. Only those advanced lines with favorable field production characteristics (earliness, compact growth habit, yielding ability and agronomic suitability) were harvested, each as $F_{5:7}$ bulks, and these were in turn evaluated for yield (g plant^{-1}), seed weight (g 100seed^{-1}) and seed color. The resulting best selections were coded as DAB lines and prepared for further analysis.

Results and Discussion: During the 2008 dry season a total of 1846 $F_{5:6}$ selections were planted over the two sites selected for testing of the AxA and AxM progeny and of these 1390 were harvested (75%). In the case of the AxA progeny (Table 26), 898 lines out of the 1354 single plant selections were harvested representing 60% of the total planted, while in the case of the AxM progeny (Table 27), almost all 492 genotypes were harvested, representing 97% of the genotypes.

Comparison of each cross combination showed that the pedigree resulting in the best average yields among the AxA cross combinations were G4523(ICA PALMAR) x NATAL SUGAR, G4523(ICA PALMAR) x RED CANADIAN WONDER and RAA21 x PAN127 with yields greater than 15 g / plant equivalent to 3000 kg ha^{-1}. In contrast the cross producing progeny with the lowest yields was AFR298 x NATAL SUGAR with average yield of 9.7 g/plant or 1950 kg ha^{-1}. Combining ability was best therefore for G4523 and worst for NATAL SUGAR and PAN127 and this was reflected in the number of selections advanced per cross combination. Average seed weight was highest with selections from ICA QUIMBAYA and RAA21, the two large-red seeded parents and was lower for G4523, SAB259 and SEQ1003 which were the mottled parents.

Among the AxM cross combinations, SER8 and SER22 were the best female combiners, SER16 and SEQ11 were intermediate and SEC16 was the worst, but mostly in combination with SUG131 and RED CANADIAN WONDER as male parents. NATAL SUGAR and PAN127 were intermediate combiners and CAL 143 was the worst combiner for the plantings in Palmira, mostly due to an undesirable green stem characteristic reflecting less mobilization of photosynthates to grain leading to lower yields. Despite this many well-adapted progeny were found from the cross of SER22 x CAL143 with average yields among the harvested genotypes of 2821 kg ha^{-1}. Lowest average yields were found for SEC 16 x NATAL SUGAR with 1168 kg ha^{-1}.

Future Plans: A total of 216 lines were selected for seed multiplication and coding as DAB lines consisting in 162 from the AxA experiment and 54 from the AxM experiment. The AxA derived lines included 41 from the crosses with ICA QUIMBAYA, 46 from crosses with G4523, 32 from crosses with SAB259, 6 from crosses with SEQ1003 and 28 from crosses with RAA21. Meanwhile the AxM derived lines included 26 from crosses with SER22, 13 from crosses with SER16, 8 from crosses with SEQ11, 7 from crosses with SER8 and none from crosses with SEC16. Grain types in the AxM lines tended to be smaller in seed weight (around 30 g 100seed^{-1}) compared to those from the AxA crosses (48 to 57 g 100seed^{-1}), as would be expected given the genepool combinations made. It was surprising that SER22 x SUG131, produced some larger seeded progeny which is why this combination was overrepresented in those that produced DAB lines from the AxM crosses. The new DAB lines will be tested in additional environments and in replicated trials. As a first set of drought trials, the DAB lines have been planted as a replicated yield trial in the January – March 2009 dry season under rainfed conditions in Palmira. These trials consist in 4 lattice design experiment each with three replications. Three of the lattices contain the 162 AxA derived lines while a fourth lattice contains the 54 AxM lines. The three Andean lattices are distinguished by seed color with large-red, red mottled and cream mottled experiments planted separately and are planted only in drought treatment. The AxM lattice has been planted under drought and irrigated treatments. Control genotypes for the lattices include the Andean DIACOL Calima and the Mesoamerican Tio Canela.

Table 26. Selections made from the Andean x Andean cross combinations.

Cross	Yield (kg ha^{-1})	Number of Harvested Lines (June - Sept 08)	CV (%)	Weight of 100 seeds (g)	Number of DAB lines*
AFR 298* x CAL 143	2769	111	30	58	31
AFR 298 x SUG 131	2433	56	39	63	6
AFR 298 x NATAL SUGAR	1950	28	25	54	1
AFR 298 x PAN 127	2162	33	28	54	3
AFR 298 x RC WONDER	2257	105	35	57	9
Total	**2314**	**228**	**-**	**57**	**41**
G 4523 x CAL 143	2478	107	30	50	13
G 4523 x NATAL SUGAR	3125	33	27	50	12
G 4523 x PAN 127	2655	11	30	48	5
G 4523 x RC WONDER	3188	37	37	50	16
Total	**2861**	**188**	**-**	**49**	**46**
SAB 259 x CAL 143	2940	38	28	47	18
SAB 259 x SUG 131	2561	31	23	52	7
SAB 259 x NATAL SUGAR	2057	41	23	48	1
SAB 259 x PAN 127	2066	36	26	47	3
SAB 259 x RC WONDER	2047	31	20	47	3
Total	**2334**	**177**	**-**	**48**	**32**
SEQ 1003 x CAL 143	2233	29	33	49	4
SEQ 1003 x NATAL SUGAR	2071	32	35	49	0
SEQ 1003 x PAN 127	2407	20	28	45	0
SEQ 1003 x RC WONDER	2041	16	32	51	2
Total	**2188**	**97**	**-**	**49**	**6**
RAA 21 x CAL 143	2819	69	27	50	19
RAA 21 x SUG 131	2389	26	29	54	4
RAA 21 x NATAL SUGAR	2640	17	43	56	2
RAA 21 x PAN 127	3186	2	27	57	1
RAA 21 x RC WONDER	2627	24	27	51	2
Total	**2732**	**138**	**-**	**53**	**28**
Total of DAB line (AXA)					**162**

* AFR 298 = ICA Quimbaya

Table 27. Selections made from the Andean x Mesoamerican cross combinations.

Cross	Yield (kg ha^{-1})	Number of Harvested Lines (June - Sept 08)	CV (%)	Weight of 100 seeds (g)	Number of DAB lines*
SER 8 x CAL 143	1402	5	22	35	0
SER 8 x SUG 131	1890	26	34	32	4
SER 8 x NATAL SUGAR	2062	9	28	32	0
SER 8 x PAN 127	1980	33	27	29	1
SER 8 x R C WONDER	2420	7	31	36	2
Total	**1951**	**80**	**-**	**33**	**7**
SER 16 x CAL 143	2095	26	43	31	0
SER 16 x SUG 131	1978	24	45	32	2
SER 16 x NATAL SUGAR	2402	21	37	27	4
SER 16 x PAN 127	2714	18	51	31	4
SER 16 x R C WONDER	2533	12	28	32	3
Total	**2344**	**101**	**-**	**31**	**13**
SER 22 x CAL 143	2822	23	29	33	1
SER 22 x SUG 131	2794	51	32	36	16
SER 22 x NATAL SUGAR	1950	59	35	31	6
SER 22 x PAN 127	2119	36	22	30	3
Total	**2421**	**169**	**-**	**32**	**26**
SEC 16 x CAL 143	1777	2	9	24	0
SEC 16 x SUG 131	1863	11	20	29	0
SEC 16 x NATAL SUGAR	1168	17	32	30	0
SEC 16 x PAN 127	1744	8	55	28	0
SEC 16 x R C WONDER	1389	14	31	29	0
Total	**1588**	**52**	**-**	**28**	**0**
SEQ 11 x CAL 143	1692	22	52	30	1
SEQ 11 x SUG 131	1853	7	43	35	1
SEQ 11 x NATAL SUGAR	1905	19	35	27	3
SEQ 11 x PAN 127	1852	15	47	27	1
SEQ 11 x R C WONDER	2114	14	29	42	2
Total	**1883**	**77**	**-**	**32**	**8**
Total of DAB lines (AxM)					**54**

Contributors: M.W. Blair, V. M. Durán, F. Monserrate (SBA-1, CIAT), G. Makunde (DR4D-Zimbabwe), S. Beebe (CIAT-HQ), R. Chirwa (CIAT-Malawi), D. Lungu (Univ. of Zambia)

2.1.1.5 Field evaluation of a common bean reference collection for drought tolerance

Rationale: Common bean improvement relies heavily on the genetic diversity of parental sources used for various purposes in a breeding program. The widest genetic diversity for cultivated germplasm is thought to exist in landraces and yet these have not been widely exploited in most common bean improvement projects, although they have been important for finding sources of insect or disease resistance (Singh, 2001). Screening of a core collection of mostly landraces has also been useful for finding new sources of low fertility tolerance. Broadening of the genetic base for cultivated common bean and for specific commercial classes of beans is very important given the narrow genetic based of some cultivar groups (Kelly, 1999), especially within the Andean genepool (Beaver et al., 1999). The objective of this work was to screen part of the CIAT core collection (termed a reference collection) for the identification of new sources of drought tolerance among bush bean landraces. In the process, a large number of phenotypic traits associated with drought tolerance were considered. The reference collection is a smaller more manageable subsample of the core collection and has been selected based on molecular marker fingerprinting to represent most of the diversity in cultivated common bean and in the initial collection. It also is a collection with a well-understood population structure based on the previous molecular analysis which allows it to be efficiently analyzed for marker associations, something that was not possible previously with quantitative traits and with a loosely understood collection. Given this, the reference collection was carefully stratified according to Andean and Mesoamerican genepools with known subdivisions according to each of the common bean races that we validated in previous studies.

Materials and Methods: A total of 199 genotypes were evaluated in the July-September 2008 season across three location/treatment combinations: 1) Darién – rainfed; 2) Palmira – rainfed and 3) Palmira – irrigated. Of these genotypes, 169 belonged to the CIAT core collection and 30 were additional genotypes added to create the reference collection and considered as checks (12 Andean controls and 18 Mesoamerican controls). The genotypes were stratified according to gene pool with separate experiments for the Andean genotypes (64 entries in an 8 x 8 lattice) versus the Mesoamerican genotypes (121 entries in an 11 x 11 lattice). Soil conditions in Palmira (Aquic Haplustoll, pH= 7.7 and available P levels of 67 to 77 ppm) were fairly different than in Darién (Andic Dystrudept, pH 5.7 and 2 to 6 ppm available P) and fertilizer application was necessary in the latter location (400 kg ha^{-1} of diammonium phosphate, supplying 79 kg ha^{-1} P) but not in Palmira. In addition the altitude difference in Palmira (1000 masl) versus Darién (1500 masl) led to differences in adaptation to climate regimes. For example in Palmira minimum and maximum temperatures varied between 17 / 25 °C for lows and 25 / 33 °C for highs while in Darién average temperatures were 16°C (average low) to 25°C (average high). Rainfall also varied with 163 mm unevenly distributed during the growing season in Palmira compared to Darién where 280 mm rain fell but mostly towards the end of the season (R7 and R8 pod filling growth stage). Drought stress was therefore more intense but intermittent in Palmira with severe stress around early establishment (V2 and V3 growth stages) compared to Darién where it was moderate but early.

For Palmira, two treatments were implemented, one with adequate irrigation and one with rainfed conditions (i.e. to induce drought stress after establishment). Both treatments were established with three early gravity irrigations of about 35 mm each at (-1, 15 and 34 days from/after planting). The irrigated treatment received three additional gravity irrigations of the same amount at approximately 1.5 to two week intervals (45, 55 and 72 days after planting).

Data collection: In all three environments data were collected on basic phenological and yield component traits. These included days to flowering (DF), days to maturity (DM), yield (kg ha^{-1}), number of pods per plant, number of seed per pod and number of empty pods. Physiological measurements including chlorophyll content (SPAD), stomatal conductance (mmol m^{-2} s^{-1}), photosynthetic efficiency (Fv′/Fm′), canopy temperature depression (°C) and leaf area index were also taken during the R6 to R7 growth stage. Scatterplots were made to graphically represent the rainfed (drought) versus irrigated (control) averages for each trait and each genotype. In addition, the data were used for a principal component analysis (PCA) to determine the relatedness of genotypes from each race within each gene pool based on the phenological, physiological and yield traits.

Results and Discussion: Preliminary analysis was conducted separately for each experiment representing each gene pool and each growing environment (Table 28 and Figures 13 and 14). Average yields across all Andean genotypes were 1644 kg ha^{-1} in rainfed treatment in Palmira, 1614 kg ha^{-1} in rainfed treatment in Darién and 1016 kg ha^{-1} in irrigated control treatment in Palmira. Meanwhile, average yields across all Mesoamerican genotypes were 1724 kg ha^{-1}in rainfed treatment in Palmira, 1941 kg ha^{-1} in rainfed treatment in Darién and 1596 kg ha^{-1} in irrigated control treatment in Palmira. The lower yields in the irrigated control treatment in Palmira were due to *Sclerotium rolfsii* infection. This root rot is favored in the warm, alternating humid-and-dry conditions of the irrigated treatment during the dry season and was more prevalent in the field used for irrigated treatment which is not tiled as compared to the field which is used for rainfed treatment which was tiled for additional drainage. The lower yields of the irrigated field made some comparisons of yield potential and drought effects difficult. For example, least significant differences were higher in the irrigated control treatment in Palmira than in the rainfed treatments in both sites, also reflecting the variability in disease incidence. However, the results of the two rainfed treatments in Palmira and Darién allowed us to analyze the effects of different stress treatments on the different genotypes while the comparison of the drought and irrigated treatments allowed us to analyze the effect of the irrigation treatment and disease pressure on these same genotypes. Below we summarize some results for the genotypes tested from each gene pool.

Table 28. Average yields, days to flowering and maturity, 100 seed weight and % empty pods in Andean and Mesoamerican genepools, races and subgroups as compared to control genotypes used in the reference collection experiments.

	Yield (kg ha^{-1})			Days to Flowering			Days to Maturity			Weight of 100 seeds (g)			Empty Pods (%)		
Race	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Andean genepool															
Nueva Granada 1	1717	1213	1580	37	41	47	40	43	43	33	34	39	67	68	78
Nueva Granada 2	1384	1110	1541	30	37	43	42	36	37	35	36	40	69	71	80
Perú	1011	756	1437	36	40	47	41	45	38	38	39	43	78	76	83
Total Andean	1395	1053	1527	34	39	46	41	41	39	35	36	40	71	71	80
Andean checks															
SAB 645	2596	463	1779	34	45	57	35	20	62	29	34	36	62	60	79
SEQ 1003	2566	2110	1486	40	45	48	25	41	54	34	35	43	67	69	82
CAL 96	2290	997	1653	53	59	65	34	36	53	33	33	38	67	70	81
KAT B1	2285	1170	1703	38	39	35	30	51	39	28	28	38	60	63	81
AFR 298	2209	1442	1232	46	51	57	35	44	44	32	33	38	68	72	80
URUGEZI	1962	1396	1500	46	32	44	36	16	49	36	36	42	70	68	79
SEQ 1027	1927	1960	1777	36	44	55	30	7	30	38	36	46	69	73	82
KAT B9	1900	1919	1525	39	43	48	33	38	34	28	29	36	58	62	75
SELIAN97	1689	2540	2445	22	28	28	32	26	17	37	36	40	70	67	74
CAL 143	1586	1568	1969	32	44	50	34	31	44	34	34	38	68	70	80
AFR 619	1492	2531	1954	36	65	45	42	25	29	36	37	42	70	77	79
SAB 258	1459	1451	1365	33	34	39	41	24	42	28	27	35	60	60	73

Table 28. cont´d.

Race	Yield (kg ha^{-1})			Days to Flowering			Days to Maturity			Weight of 100 seeds (g)			Empty Pods (%)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Mesoamerican genepool															
Durango 1	1742	1385	1847	31	31	36	68	64	72	33	33	37	51	62	54
Durango 2	1678	1743	1986	35	35	39	69	69	76	21	23	24	40	40	35
Guatemala	1240	1268	1895	35	34	39	71	70	78	24	26	28	46	46	41
Mesoamerican 1	1764	1573	2116	38	37	40	69	69	76	21	23	23	41	31	30
Mesoamerican 2	1780	1742	2002	37	36	40	70	69	75	20	25	23	42	34	28
Total Mesoamerican	1702	1597	1997	36	35	39	69	68	75	23	25	26	43	39	35
Mesoamerican checks															
SEA 15	3292	2871	2481	32	31	37	68	62	76	34	33	35	28	39	48
DOR 390	2917	1812	2439	39	42	43	71	77	80	17	20	20	19	21	23
SXB 418	2912	2430	2437	38	36	39	70	67	74	28	29	28	27	22	44
SER 16	2863	1789	2864	33	32	37	66	62	74	25	24	25	31	5	24
SER 118	2854	2962	2658	37	36	39	69	67	75	25	27	30	19	13	19
NCB 280	2835	1926	2582	32	31	37	66	63	77	26	24	31	43	28	41
BAT 477	2690	1637	2076	38	37	40	69	74	77	21	22	22	46	32	27
SER 109	2597	2124	1528	31	33	37	67	67	75	26	27	26	60	28	21
SEA 5	2505	2169	1443	33	32	37	67	66	61	26	29	32	38	17	24
VAX 6	2494	2194	2194	38	38	41	69	71	77	22	24	23	25	26	14
A. MELKA	2375	2019	2336	41	39	43	73	74	66	16	20	14	27	17	20
T.CANELA75	2357	1447	2065	39	37	42	69	69	78	21	22	23	33	32	31
VAX 3	2083	2332	2827	37	37	40	69	69	79	25	30	27	31	20	26
SEQ 11	2049	3052	1890	34	33	37	70	70	75	29	30	29	23	30	33
M. SOJA	1974	1269	2813	38	38	43	73	69	81	21	21	23	38	36	15
P. VILLA	1715	1497	2036	28	30	36	65	60	72	37	34	36	74	59	45
BAT 93	1676	1218	2302	38	37	42	69	69	77	18	19	20	50	42	31
M. RED	1472	1439	1790	37	36	39	73	77	77	22	24	28	32	46	24

Environments: Rainfed with intermittent drought stress (1) and Irrigated (2) in Palmira. Rainfed with moderate drought stress (3) in Darién
* Andean Race: P- Perú, NG1 – Nueva Granada 1, NG2- Nueva Granada 2
** Primary and Secondary Seed Color:
1 - White; 2 - Cream; 3 - Yellow; 4- Brown; 5 - Pink; 6 - Red; 7 - Purple; 8 - Black; 9 - Others

Andean genotypes: The best yielding genotypes among the Andean reference collection genotypes were G11727 (2230 kg ha^{-1}) in Darién –rainfed; G18255 (2455 kg ha^{-1}) in Palmira –rainfed and LRK31 (2018 kg ha^{-1}) in Palmira – irrigated control. Among the check genotypes the best were SELIAN97 (2445 kg ha^{-1}) in both Darién – rainfed and Palmira – irrigated as well as SEQ1003 (2566 kg ha^{-1}) and SAB645 (2596 kg ha^{-1}) in Palmira – rainfed. On the other hand, a number of Andean genotypes from the reference/core collection were very poorly adapted, yielding nothing at all in either the Palmira – rainfed (G19831, G11787, G19841) or Palmira – irrigated (G19841) treatments. Darién was a more favorable location for Andean genotypes due to the cooler temperatures encountered there during the growing season.

Figure 13A – ScatterPlot for Yield: Drought in Palmira vs Non-Drought in Palmira

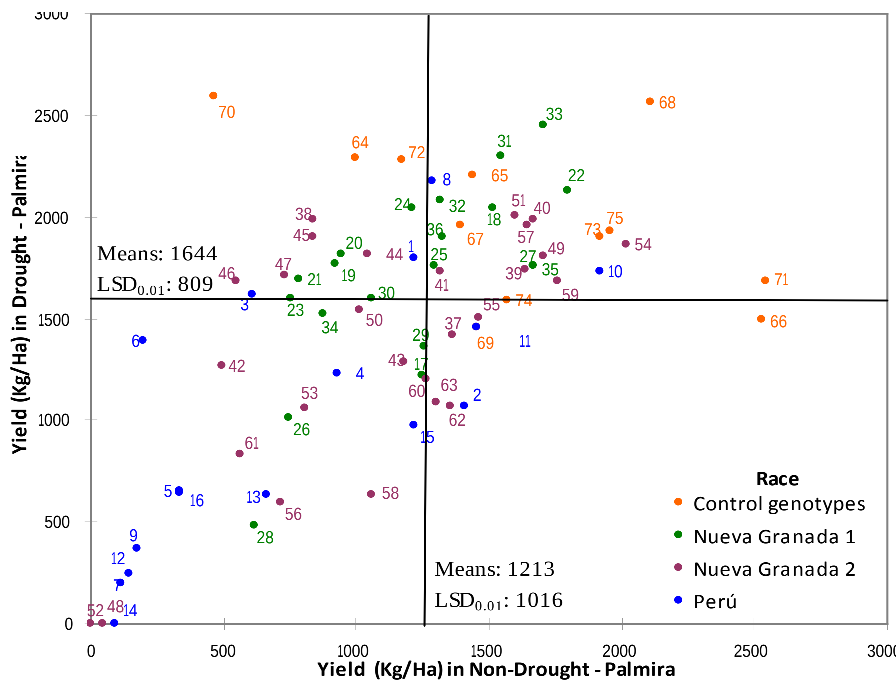

Figure 13B – ScatterPlot for Yield: Drought in Palmira vs Moderate Drought in Darien

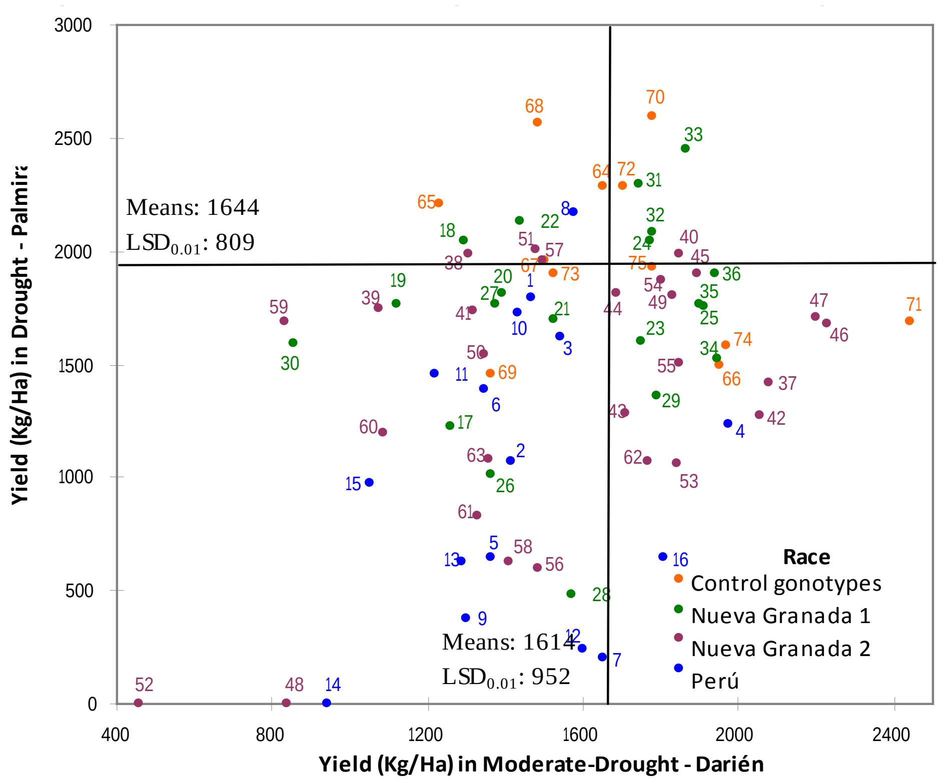

Figure 13C – PCA for Yield, Empty pods and Weight per 100 Seeds

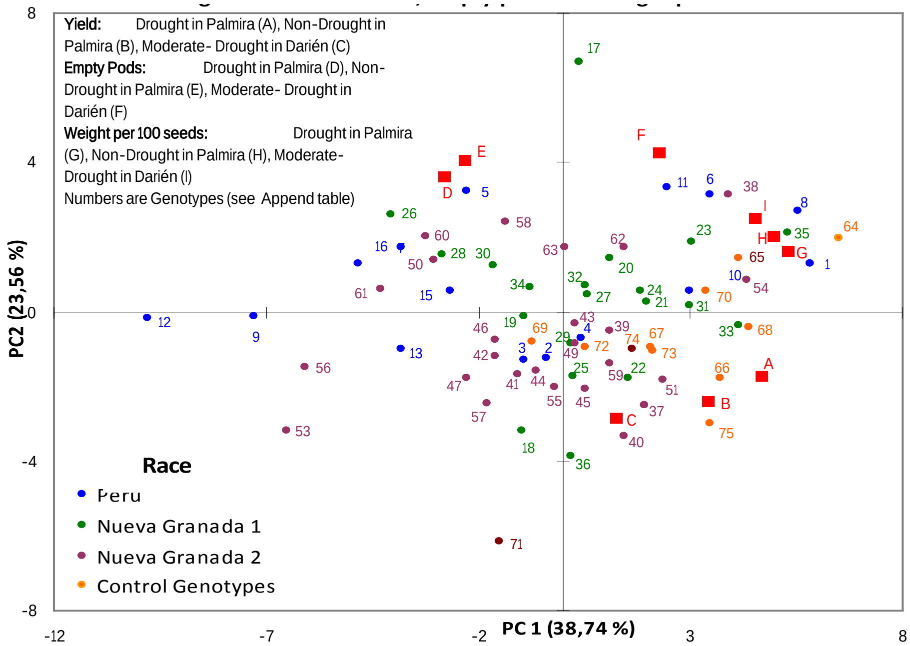

Figure 13D – PCA for Yield and Weight per 100 Seeds

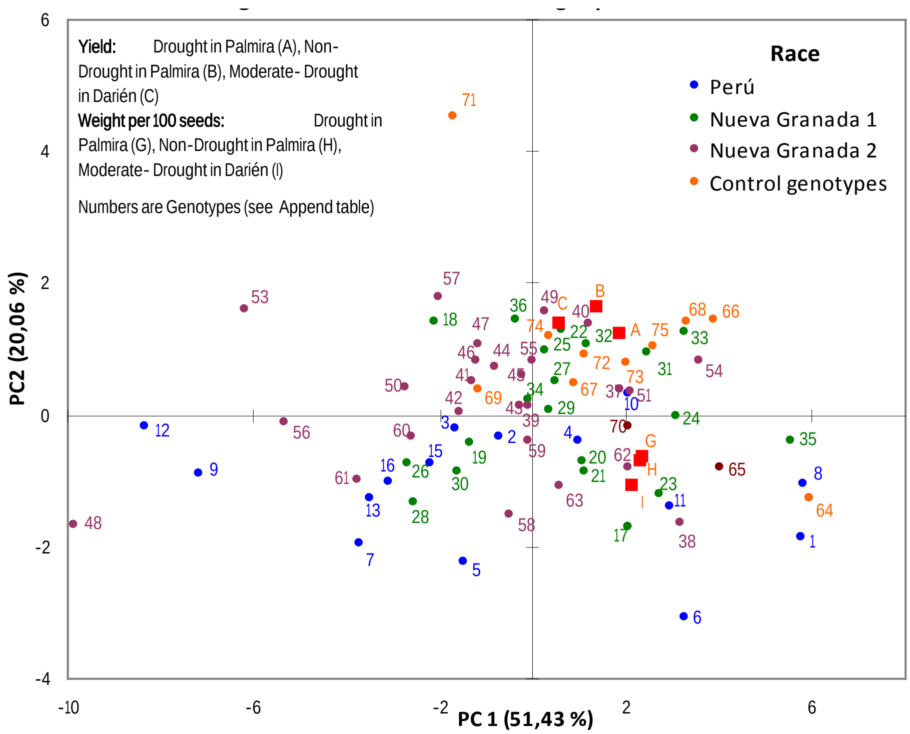

Figure 13. Results of rainfed and irrigation treatments in the Andean 8x8 lattice.

Figure 14A – ScatterPlot for Yield: Drought in Palmira vs Non-Dought in Palmira

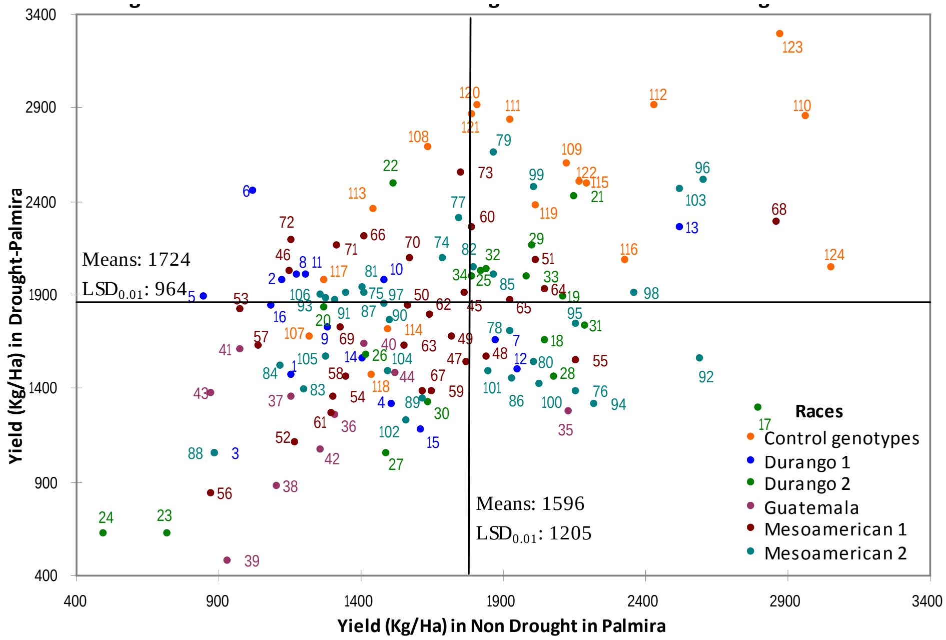

Figure 14B – ScatterPlot for Yield: Drought in Palmira vs Moderate-Dought in Darien

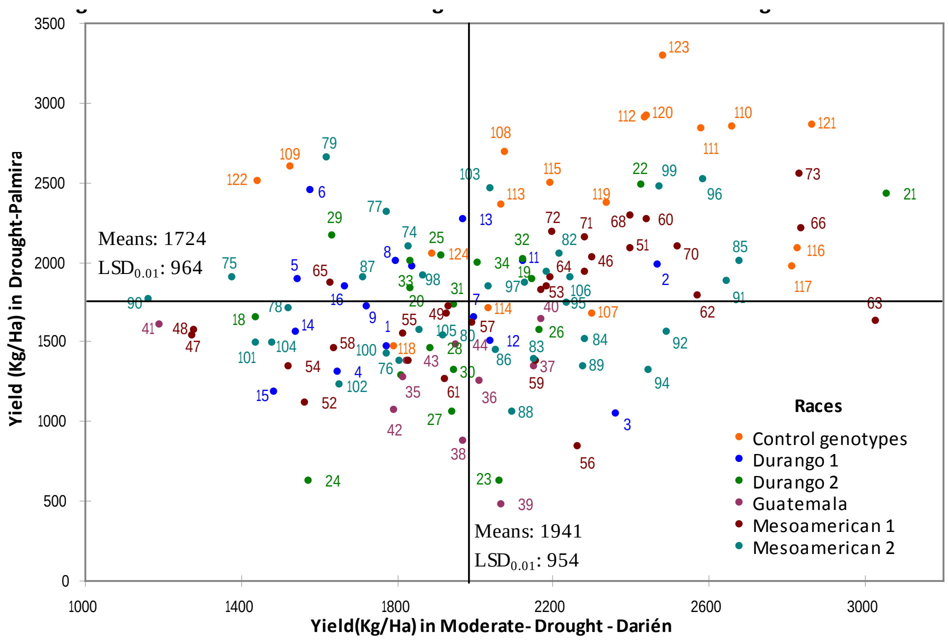

Figure 14C – PCA for Yield, Empty pods and Weight per 100 Seeds

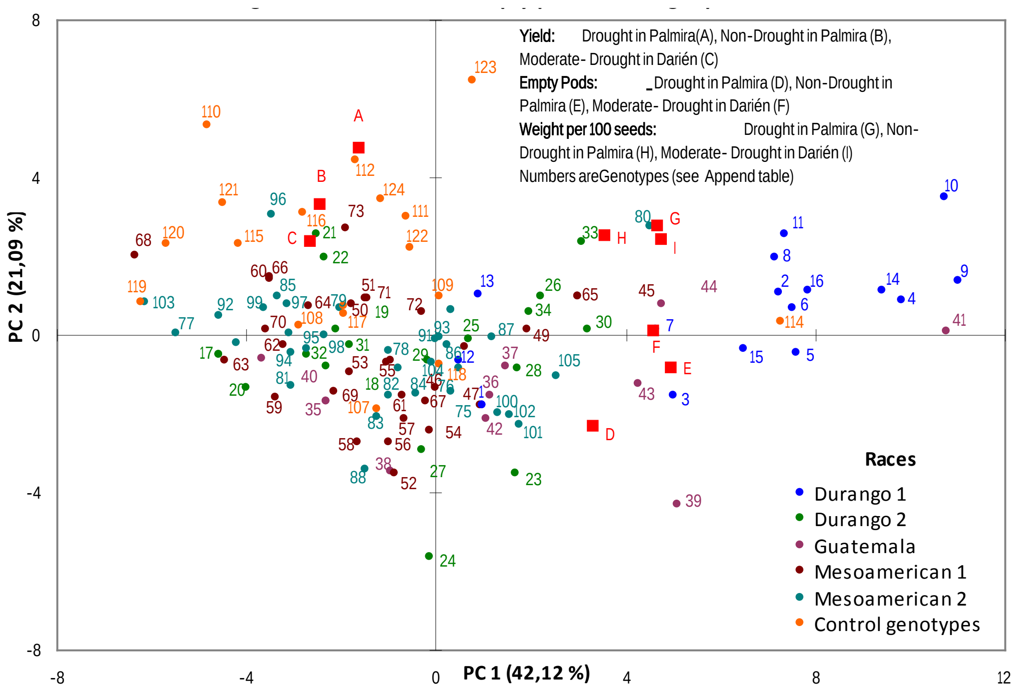

Figure 14D – PCA for Yield and Weight per 100 Seeds

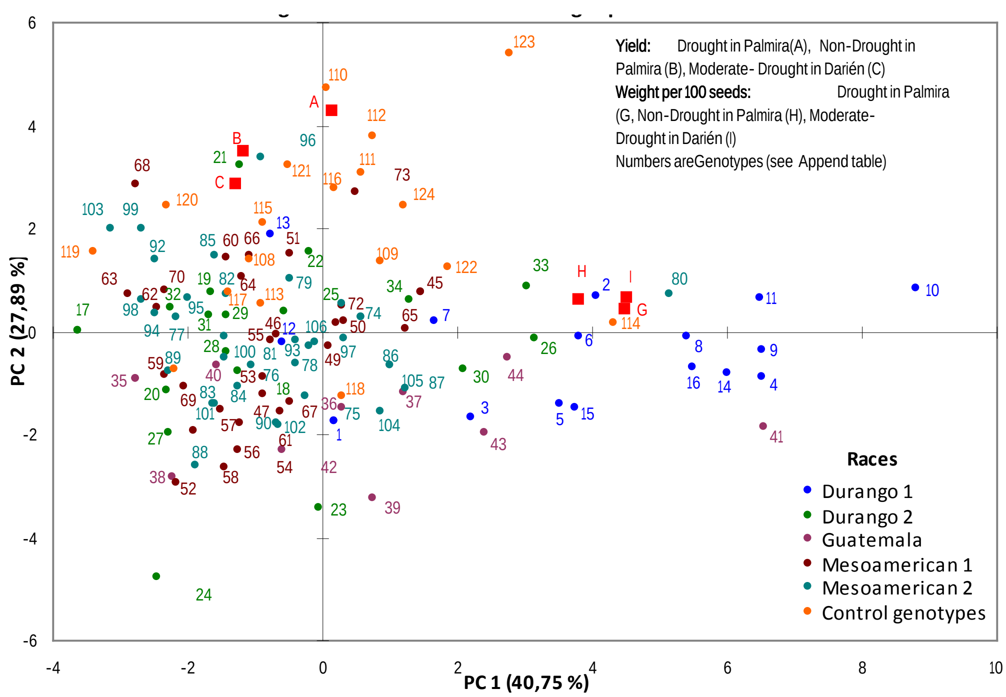

Figure 14. Results of rainfed and irrigation treatments in Mesoamerican 12 x 12 lattice.

Scatterplot comparisons were made between the drought and irrigated treatments in Palmira (Figure 13A) and between the Palmira and Darién rainfed treatments (Figure 13B) to detect the stability of each genotype and to compare the different races/groups. These comparisons showed that check genotypes were more resistant to this stress and higher yielding generally than the majority of the reference collection genotypes. This was to be expected since the checks were selected to be drought tolerant and high-yielding while the reference collection represents diverse landraces which have not been improved through breeding. Meanwhile, the Nueva Granada group NG1 was higher yielding generally than group NG2 or than race Peru, which shows the adaptation of some Nueva Granada race bush beans to hotter and drier conditions than race Peru bush beans.

Mesoamerican genotypes: The best yielding genotypes among the Mesoamerican reference collection genotypes were G4017 (3055 kg ha^{-1}) and G5694 (3025 kg ha^{-1}) in Darién – rainfed; G3142 (2660 kg ha^{-1}) and G21212 (with 2551 kg ha^{-1}) in Palmira – rainfed; and G278 (2799 kg ha^{-1}) and G2199 (2864 kg ha^{-1}) in Palmira – irrigated control. It was evident that the Mesoamerican genotypes had a higher yield potential than the Andean genotypes in all three environments. Furthermore, there were no Mesoamerican genotype that failed to produce seed in any of the environments and the lowest yields were 1164, 475 and 497 kg ha^{-1}, respectively; with Darién under moderate level of water stress being more productive generally for Mesoamericans than Palmira with irrigation or under drought stress. This may be the result of cooler temperatures in Darién and heat stress being a factor in Palmira as well as disease pressure from *Sclerotium rolfsii* as mentioned above.

Using the same Scatterplot comparisons as described for Andean genotypes, the Mesoamerican control genotypes were found to generally outperform the reference collection genotypes, although some Mesoamerica race and Durango-Jalisco group 2 genotypes were also high yielding. Durango-Jalisco group 1 genotypes were found to perform lower as did Guatemala race genotypes. The race Guatemala genotypes are normally climbing beans, therefore the production system of non-trellised field grown plants was not favorable for them, a factor that probably was also important for some of the Durango-Jalisco genotypes.

Principal component analysis: Principal component analysis was also used to determine the relationships between the genotypes and corresponding groups within each gene pool considering the variables for yield, 100 seed weight, and percent empty pods in the three environments (subfigures C and D of Figures 13 and 14).

Biplots showed the separation of the subgroups and races discussed above, especially the separation of Mesoamerica and check genotypes from Durango-Jalisco group 1 genotypes within the Mesoamericans and Nueva Granada versus Peru race genotypes in the Andeans. This confirmed something observed in the field which was the poor adaptation of “Durango” type cultivars to the tropical environments of Palmira and Darién, both in terms of overall vegetative growth and disease pressure (mainly powdery mildew and *Sclerotium rolfsii*) and the high levels of flower abortion in the case of Peru race genotypes.

Biplot analysis also showed that high yield in the three environments (letters A, B and C in the PCA) was associated with the check genotypes while empty pods (letters D, E and F) were associated with the less adapted groups (race Peru for the Andeans and the Durango-Jalisco group 1 genotypes for the Mesoamericans) and that these two characteristics were located in opposite quadrants as would be expected. Seed size (letters G, H and I) was associated with some genotypes of races Peru and Nueva Granada as well with certain race Durango and Guatemala accessions. Empty podding (lack of seed filling) was negatively correlated with yield potential, a reflection of heat and drought stress symptoms. Meanwhile, seed size was somewhat correlated with yield potential since drought tolerant genotypes filled seed better than drought susceptible genotypes.

Conclusion and Future Plans: This project was useful because we were able to establish a rainfed season planting in Darién to simulate moderate level of water stress, something which had not been done before, and we were able to obtain reliable data from that location for moderate drought stress tolerance in Andean beans. Conditions at our new site were equivalent of moderate drought stress throughout the season which would be typical of many growing environments where beans face this stress. Likewise, Palmira presented good intermittent drought stress conditions but heat stress may be a confounding factor in some cases for Andean or Durango race beans. Conditions in Palmira presented moderate stress with intermittent drought consisting in only 23 mm of rainfall between V2 and V3 stages and 47 mm between R6 and R8 stages. In terms of the genotypes evaluated from the reference collection and the check genotypes, interesting results were obtained differentiating the best accessions within each race and obtaining an understanding of differences between each group (races Durango Jalisco 1 and 2, Guatemala, Mesoamerica, Nueva Granada 1 and 2, Peru). It was notable that better adaptation was found in the Nueva Granada group 1 than in NG2 or in race Peru and that within the Mesoamerican genotypes, race Mesoamerica and Durango Jalisco group 2 were better adapted than Durango Jalisco group 1 or race Guatemala. This may be due to photoperiod, relative humidity and prevalent diseases at the altitudes the two sites used compared to the region to which these genotypes are better adapted and highlights the challenge of using Durango genotypes in cultivar development for the sub-humid tropics.

Apart from the 8 x 8 and 12 x 12 lattices another small lattice of 36 genotypes (6 x 6 lattice) was also planted and will be analyzed soon. The genotypes have also been re-arranged into a larger Andean lattice design experiment as well as the Durango-Jalisco-Mesoamerica experiment, for testing in Eastern and Southern Africa as part of the TL1 drought project. From this study, the Nueva Granada genotypes G18255 (33), G16115 (31), G4001 (22), G17070 (32), G1688 (18), G5625 (24), G22247 (36), G6639 (25), G7945 (27), G11957 (29) are of interest for further studies or use in breeding of drought tolerance. Among the Mesoamerican genotypes, a large number of lines could be of interest but the G21212 genotype stands out as was found previously by CIAT researchers. Further analysis will be conducted to evaluate drought sensitivity indices and comparisons of drought versus control values for a number of phenotypic traits in Palmira and severe versus moderate drought across the two sites to determine the relative effect of drought on trait expression in the genotypes. In addition, further statistical analysis as well as the analysis of variance (ANOVA) are ongoing. Finally, the new lattices will probably be planted in the June-September drought season in Palmira and Darién to test the trends identified so far.

2.1.1.6 Evaluation of Andean breeding lines for adaptation to drought stress

Rationale: As part of the drought screening activities described in the previous section, we have evaluated additional breeding lines for drought tolerance at a mid-elevation site useful for selecting Andean beans and instituted a dry season planting. The breeding lines (SAB series) are the product of recurrent selection for drought stress tolerance and earliness in CIAT headquarters and were tested in a new field in Darien in replicated yield trials during the July-August dry season. The SAB lines have Andean grain types and are of red mottled, cream mottled, large-red and large white commercial classes. These genotypes were developed from triple crosses between the drought-resistant genotype ICA QUIMBAYA crossed with drought susceptible but commercial type genotypes ABA36, ABA58 and COS16 and drought sources from the first cycle of selection (such as SAB258 and SAB259) that were derived from multiple crosses including a Durango source. Since ICA QUIMBAYA has wide adaptation we decided to test the resulting lines under mid-elevation conditions but with an off-season planting to coincide with drought stress.

Materials and Methods: A total of 5 yield trials were planted in Darién (Valle del Cauca, Colombia) during the July-August dry season in 2008. The soils in Darién are Andic Dystrudept and the site is located at 1500 masl elevation with average temperature of 19°C. A new field was used for the experiment to reduce the chances of root rot against which ICA Quimbaya and many SAB lines are highly susceptible. The soil pH was 5.7 and available P levels were 2 to 6 ppm, which were supplemented with 90 kg ha^{-1} of P fertilizer. The yield trials were organized as lattice design experiments with each trial containing SAB lines of a different commercial seed color class and 3 repetitions each. The first two experiments consisted in separate 6x6 lattices for red mottled and cream mottled grain types, respectively. The second two experiments consisted in separate 5x5 lattices for large-red and large-white grain types, respectively while a fifth lattice consisted on a 4x4 lattice with additional red mottled, cream mottled and large red lines. In addition the following check genotypes were included in the experiments: AFR298 (=ICA Qumbaya; large-red), COS16 (cream mottled), ABA36 (large-white), SAB560 (large red) and the local commercial variety Calima (red mottled).

Results and Discussion:

Rainfall pattern: Growing conditions during the season were appropriate for drought testing since total rainfall was 280 mm. Soil texture was heavier than in our previous fields in Darién, so residual water from the rainy season probably supplemented this moisture level. Drought stress was highest early in the season and especially soon after flowering since 198 mm of the rain during the season fell during pod filling (R7-8). Meanwhile, temperatures varied from 16 to 25 °C during the growth cycle.

Yield data: Genotype yields for the five experiments are summarized in Figure 15 which compares the average yield in kg ha^{-1} for the check genotypes and advanced lines from each commercial class. In that figure each lattice is represented as a column of datapoints with the least significant difference (LSD) given at the base of the column and the check genotypes highlighted as diamonds.

Comparisons of the trials, shows that the average yields of the large-red lines (column C) were higher than for the red mottled and cream mottled lines (columns B and D), while the lowest yields were in the lattices with the large-white beans (column E) and the mixed group (column A). Meanwhile, comparisons of the SAB lines with the check genotypes shows that for all of the trials (columns A through E), some of the advanced lines were significantly superior to the controls (AFR298, CALIMA, COS16 and ABA36) based on the LSD for each trial. For example, SAB 663 with an average yield of 2047 kg ha^{-1} was significantly higher yielding than the check genotype CALIMA with 1472 kg ha^{-1} within column B for the 6x6 red mottled trial (LSD = 560 kg ha^{-1}). As expected in all the lattices except the 4 x 4 lattice (column A), AFR298, the moderately drought tolerant parent, had higher yields than COS16 or ABA36, which were susceptible parents although again these differences were not significant. Surprisingly AFR298 and Calima performed about equally well.

Conclusions and Future Plans. In general, the results confirm the genetic gain for drought tolerance and yield potential that has occurred in the breeding of the SAB lines compared to both their drought-tolerant and susceptible parents. In addition, certain SAB lines can be selected with greater stability across mid-elevation and lower-elevation sites based on this analysis. The most promising series of lines appear to be those of the large-red commercial class followed by some of the cream-mottled genotypes. However, differences between the trials could have been due to the innate drought tolerance and yield potential of the genotypes in the trials or to their location in the field, since available P levels were found to vary along a gradient from the upper part to the lower part of the field (from 2.4 to 6.2 ppm), which also reflected differences in organic matter and clay content. Future plans are to repeat these yield trials in other years or locations as part of the drought projects we are developing and to evaluate if selection for drought tolerance in the advanced lines improves adaptation to low fertility conditions.

Collaborators: M.W. Blair, F. Monserrate, S. E. Beebe, M. Grajales, Y. Viera, A. Hoyos (SBA-1)

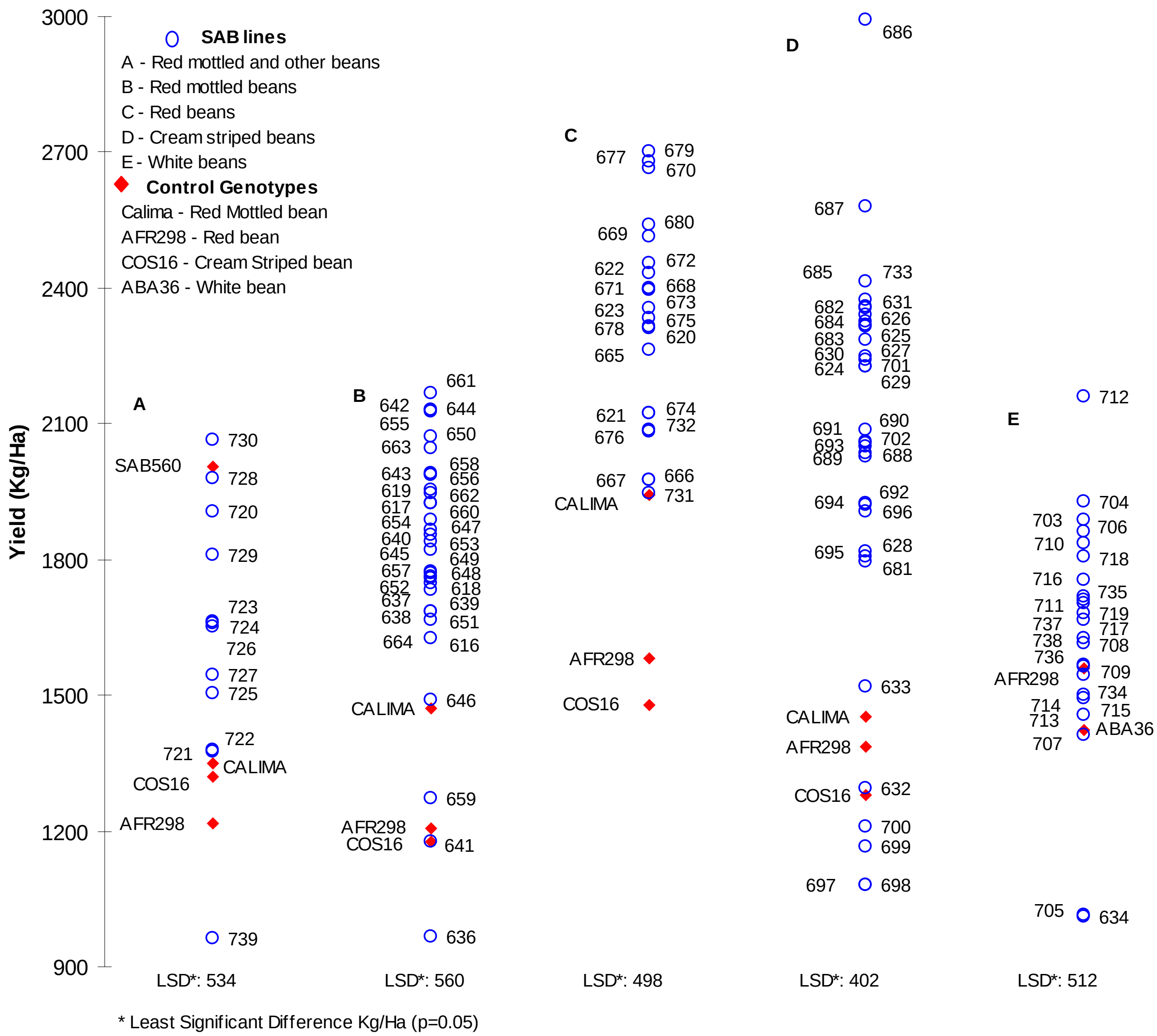

Figure 15. Comparison of average yield (kg ha^{-1}) for SAB lines planted in 5 lattice design experiments in Darién in the 2008 dry season.

2.1.1.7 Physiological evaluation of drought resistance in elite lines under field conditions

Rationale: Development of drought adapted bean varieties is an important strategy to minimize crop failure and improve food security in bean growing regions. Previous research indicated that the superior performance of common bean genotypes under drought was associated with their ability to mobilize photosynthates to developing grain and to utilize the acquired N and P more efficiently for grain production. Among the plant traits evaluated using elite lines and recombinant inbred lines, higher values of pod partitioning index, pod harvest index and stem biomass reduction were identified as useful traits to consider in the breeding program in addition to grain yield for identifying bean genotypes that are better adapted to both terminal and intermittent drought stress conditions. We evaluated drought adaptation of 36 elite lines including checks from the on-going breeding program on improving drought resistance to quantify phenotypic differences in drought resistance under field conditions and to define the physiological basis for improved drought adaptation.

Materials and Methods: A field trial was conducted at Palmira in 2007 (June to September). The trial included 36 genotypes A 686, A 774, BAT 477, Carioca, Cowpea Mouride, DOR 390, EAP 9503-32B, EAP 9653-16B-1, G19902, G24390, G40001, NCB 226, NCB 280, Perola, RCB 273, San Cristóbal 83, SEA 15, SEA 5, SEN 36, SEN 56, SER 109, SER 113, SER 118, SER 119, SER 125, SER 128, SER 16, SER 48, SER 78, SER 90, SXB 405, SXB 409, SXB 412, SXB 415, SXB 418 and Tio Canela (Table 29) to determine genotypic differences in tolerance to drought stress conditions. A 6 x 6 balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. For the irrigated treatment, a total of 4 gravity irrigations (approximately 35 mm each) were applied while for the rainfed treatment only 2 irrigations were applied to assure good crop establishment (one before planting and another 24 days after planting). Details on planting and management of the trial were similar to those reported before. Experimental units consisted of 4 rows, 3.72 m long by 0.6 m wide. A number of plant attributes were measured at mid-podfilling under rainfed conditions in order to determine genotypic variation in drought resistance. These plant traits included leaf chlorophyll content (SPAD), canopy temperature, canopy temperature depression (CTD), leaf area index, canopy dry weight per plant and shoot TNC content (total nonstructural carbohydrates).

Canopy temperature was measured with a Telatemp model AG-42D infrared thermometer. The instrument was held at a 45^{o} angle at 50 cm from the canopy surface to measure canopy temperature and canopy temperature depression. At the time of harvest, grain yield and yield components (number of pods per plant, number of seeds per pod, and 100 seed weight) were determined. Stem biomass reduction (mobilization of photosynthate reserves) was determined based on difference in stem dry weight at harvest from the stem dry weight at mid-pod filling. Pod partitioning index (dry wt of pods at harvest/dry wt of total biomass at mid-podfill x 100), pod number per area, seed number per area, pod harvest index (dry wt of seed/dry wt of pod at harvest x 100), yield production efficiency (seed biomass dry weight at harvest/total shoot biomass dry weight at mid-pod filling), seed production efficiency (seed number per area/ total shoot biomass dry weight at mid-pod filling per area), pod production efficiency (pod number per area/ total shoot biomass dry weight at mid-pod filling per area) and grain filling index (100 seed weight of rainfed/100 seed weight of irrigated) were also determined.

Eight genotypes (DOR 390, SER 16, SER 109, G40001, G24390, SXB 418, SEA 5 and Tio Canela 75) were selected to determine differences in root growth and distribution across soil depth. Root samples were taken at 53 days after planting at both levels of water supply. Samples were taken at 5 soil depths (0-5, 5-10, 10-20, 20-40 and 40-60 cm), using a 5 cm diameter soil corer. Five soil cores were taken, three cores between rows and two within rows. To facilitate washing, samples were first soaked for 30 minutes in 5% sodium hexametaphosphate solution. Soil and roots were separated by hand washing, cleaning and scanning. Root length and diameter were determined by image analysis system (WinRHIZO V. 2007b).

Results and Discussion: Palmira – Soil, temperature, rainfall and evaporation: The soil is a Mollisol (Aquic Hapludoll) with no major fertility problems (pH = 7.7), and is estimated to permit storage of 130 mm of available water (assuming 1.0 m of effective root growth with –0.03 MPa and –1.5 MPa as upper and lower limits for soil matric potential). During the crop-growing season, maximum and minimum air temperatures were 30.2 and 18.6^{o} C (Figure 16). The incident solar radiation ranged from 11.2 to 25.1 MJ m^{-2} d^{-1}. The total rainfall during the active crop growth was 235.6 mm. The potential pan evaporation was of 316.2 mm. These data on total rainfall and pan evaporation together with rainfall distribution indicated that the crop suffered intermittent drought stress during active growth and development. The mean yield under rainfed conditions was 1560 kg ha^{-1} compared with the mean irrigated yield of 2063 kg ha^{-1} (Figure 17), although the difference in drought versus irrigated yield was wider for the commercial checks.

Table 29. Origin, growth habit, seed color, days to flowering, days to maturity and 100 seed weight of 36 bean genotypes tested in a Mollisol at Palmira.

Genotype	Origin	Growth habit	Seed color	Days to flowering		Days to maturity		100 seed weight	
				Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
A 686	Colombia	2	Cream-brown	39	38	70	73	29	28
A 774	Colombia	3	Cream	37	38	68	66	28	25
BAT 477	Colombia	2	Cream	38	38	70	64	24	21
Carioca	Brazil	3	Cream-brown	39	38	68	67	28	24
Cowpea Mouride	Senegal	2	Cream	48	45	70	79	15	14
DOR 390	Colombia	2	Black	38	38	69	72	22	22
EAP 9503-32B	Honduras	2	Red	36	37	68	65	24	22
EAP 9653-16B-1	Honduras	2	Red	37	38	67	71	24	21
G19902*	Argentina	4	Cream-brown	37	37	69	67	5	7
G24390*	Mexico	4	Cream-black	44	43	80	78	4	4
G40001**	Mexico	4	White	34	32	63	60	12	12
NCB 226	Colombia	2B	Black	35	34	68	68	33	33
NCB 280	Colombia	2A	Black	33	31	65	61	29	27
Perola	Brazil	3	Cream-brown	39	40	70	73	30	27
RCB 273	Colombia	2B	Red	35	33	66	62	24	24
San Cristobal 83	Dom. Republic	2	Red-cream	38	38	70	65	30	27
SEA 15	Colombia	2	Roxo	36	31	68	60	32	34
SEA 5	Colombia	2	Cream	33	33	63	65	30	28
SEN 36	Colombia	2	Black	37	37	67	69	26	24
SEN 56	Colombia	2	Black	35	32	66	63	28	28
SER 109	Colombia	2A	Red	35	33	65	63	29	25
SER 113	Colombia	2	Red	37	35	66	64	29	28
SER 118	Colombia	2A	Red	36	36	65	65	29	28
SER 119	Colombia	2A	Red	35	33	67	63	28	27
SER 125	Colombia	2A	Red	35	32	66	62	28	29
SER 128	Colombia	2A	Red	35	32	67	63	30	29
SER 16	Colombia	2	Red	34	32	65	61	27	25
SER 48	Colombia	2	Red	35	34	65	63	34	32
SER 78	Colombia	2A	Red	36	35	65	64	24	23
SER 90	Colombia	2	Red	35	32	66	62	32	31
SXB 405	Colombia	2B	Cream	39	37	67	65	30	27
SXB 409	Colombia	2B	Cream-brown	38	38	68	66	31	28
SXB 412	Colombia	2A	Cream	37	37	67	65	28	25
SXB 415	Colombia	2A	Cream-brown	37	37	69	66	29	28
SXB 418	Colombia	2B	Cream-brown	37	38	70	67	32	28
Tio Canela 75	Honduras	2	Red	37	37	68	68	24	22

* Wild common bean
** *Phaseolus acutifolius*

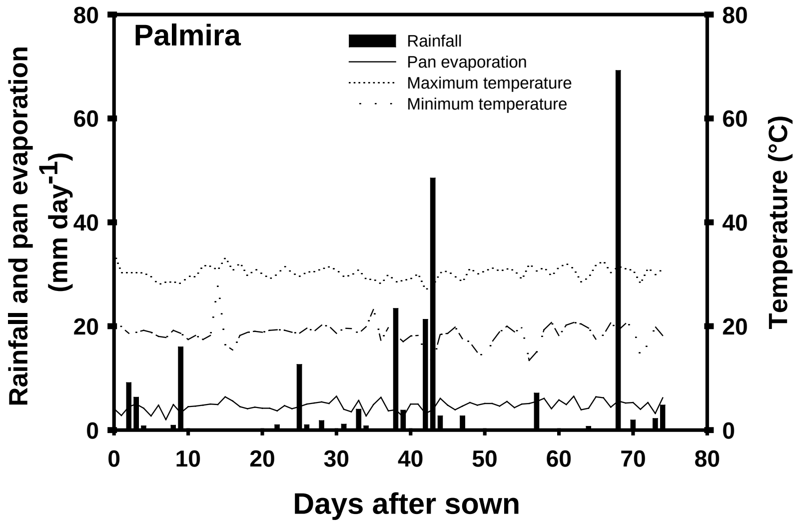

Figure 16. Rainfall distribution, pan evaporation, maximum and minimum temperatures during crop growing period at Palmira in 2007.

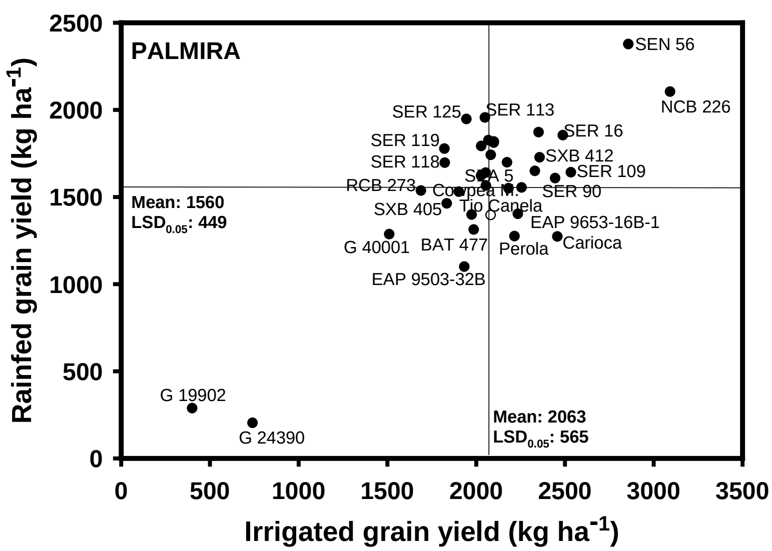

Figure 17. Identification of genotypes that are adapted to rainfed conditions and are responsive to irrigation in a Mollisol at Palmira. Genotypes that yielded superior with drought and were also responsive to irrigation were identified in the upper, right hand quadrant.

Under drought stress conditions in the field, the seed yield of 36 genotypes ranged from 200 to 2374 kg ha^{-1}. Among the lines tested, the lines NCB 226, SEN 56, SER 113, SER 125 and SER 16 were outstanding in their adaptation to rainfed (drought stress) conditions. These lines were also responsive to irrigation (Figure 17). Among the 36 lines tested, G19902 (Andean wild bean germplasm accession) and G24390 (MesoAmerican wild bean germplasm accession) were the most poorly adapted lines under both irrigated and rainfed conditions (Figure 17).

Under rainfed conditions, significant genotypic differences were observed in canopy biomass production at mid-pod filling growth stage (Figure 18). Cowpea cv. Mouride showed greater vigor than the common bean lines. However this line showed lower value of harvest index indicating a limitation on mobilization of photosynthates to pod development. Among genotypes of *P. vulgaris* tested, SEN 56 and NCB 226 were outstanding in canopy biomass production (Figure 18); also the line SEN 56 yielded well under rainfed conditions due to greater ability to partition photosynthetically assimilated carbon to seeds as reflected by higher values of harvest index (Figure 19). The line SER 118 was outstanding in its harvest index value but it had lower canopy biomass under rainfed conditions indicating the need for adequate vegetative vigor to achieve higher values of grain yield. Among the 36 genotypes evaluated, G19902 and G24390 presented the lower values of canopy biomass and grain yield (Figure 18).

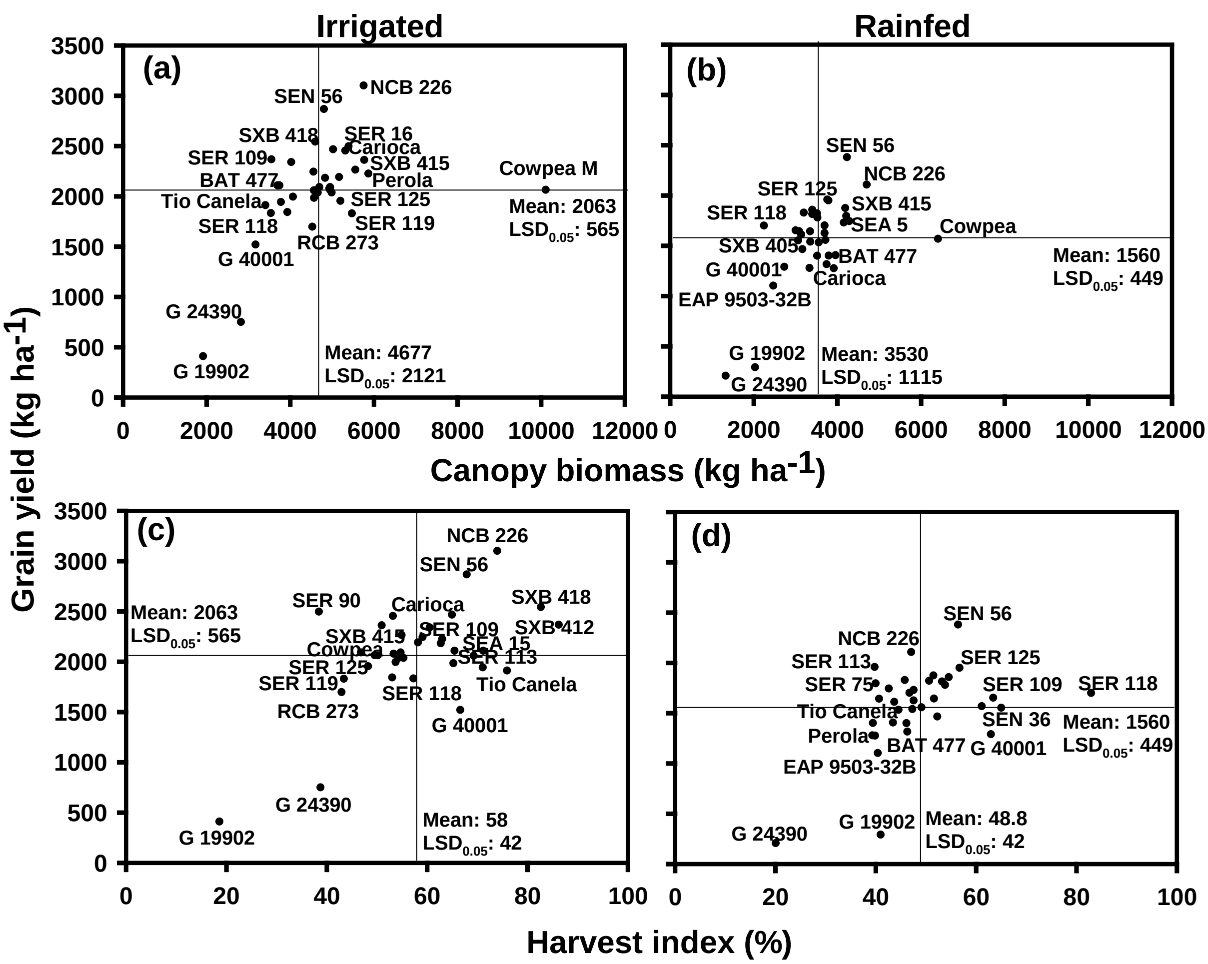

Figure 18. The relationship between grain yield and irrigated and rainfed canopy biomass (a, b) and grain yield and irrigated and rainfed harvest index (c, d) when grown in a Mollisol at Palmira.

Results on the relationship between rainfed pod harvest index (PHI) and rainfed grain yield indicated that SER 125, NCB 226 and SEN 56 were superior in mobilizing photosynthates from pod wall to seeds (Figure 19). The PHI values of G19902 and G24390 were markedly lower than that of other bean genotypes. The superior performance of lines SER 125, NCB 226 and SEN 56 was associated with greater values of pod harvest index, higher values of stem biomass reduction (Figure 19), higher values of seed and pod number per area, and 100 seed weight (Figure 20). Higher stem biomass reduction values indicate higher photosynthate mobilization from the stem to other plant structures such as pods.

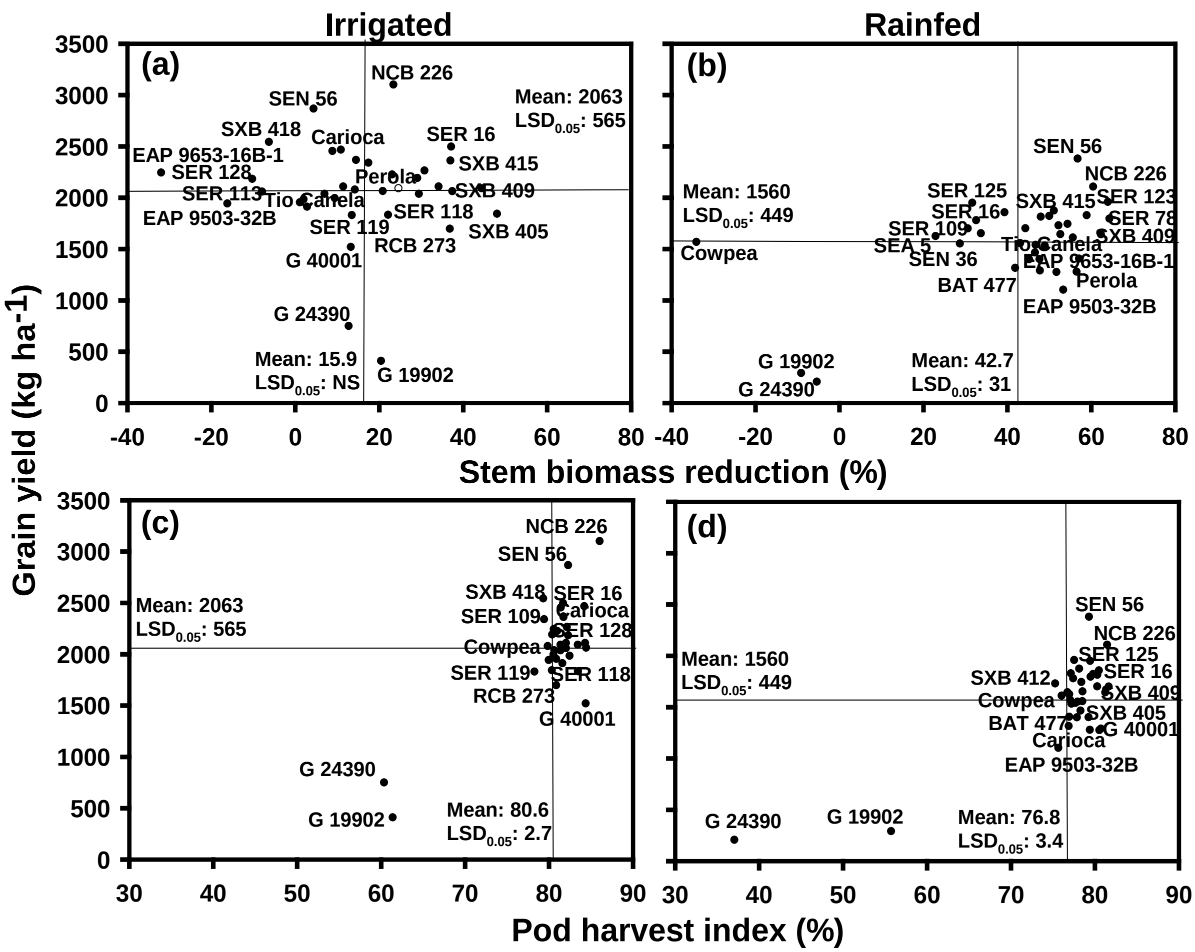

Figure 19. The relationship between grain yield and irrigated and rainfed stem biomass reduction (a, b), grain yield and irrigated and rainfed pod harvest index (c, d) when grown in a Mollisol at Palmira.

Yield production efficiency of SER 118 under rainfed conditions was outstanding and this was because of its greater value of harvest index while its canopy biomass production was only above average value (Figures 21, 18). Yield production efficiency is an integrated measure for photosynthate mobilization and SER 118 could be an excellent parent to improve yield under rainfed conditions.

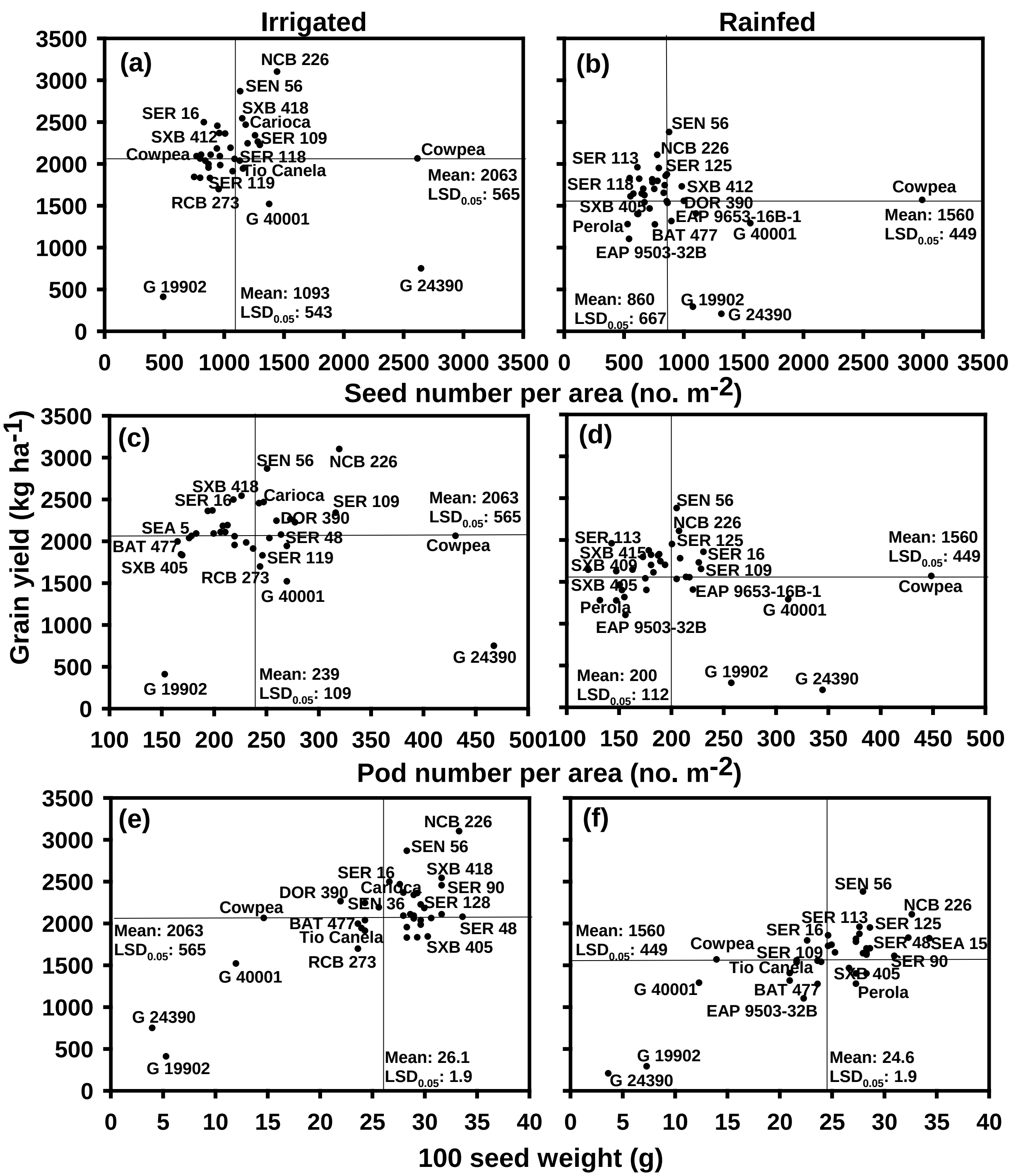

Figure 20. The relationship between grain yield and irrigated and rainfed seed number per area (a, b), grain yield and irrigated and rainfed pod number per area (c, d), and grain yield and irrigated and rainfed 100 seed weight (e, f) when grown in a Mollisol at Palmira.

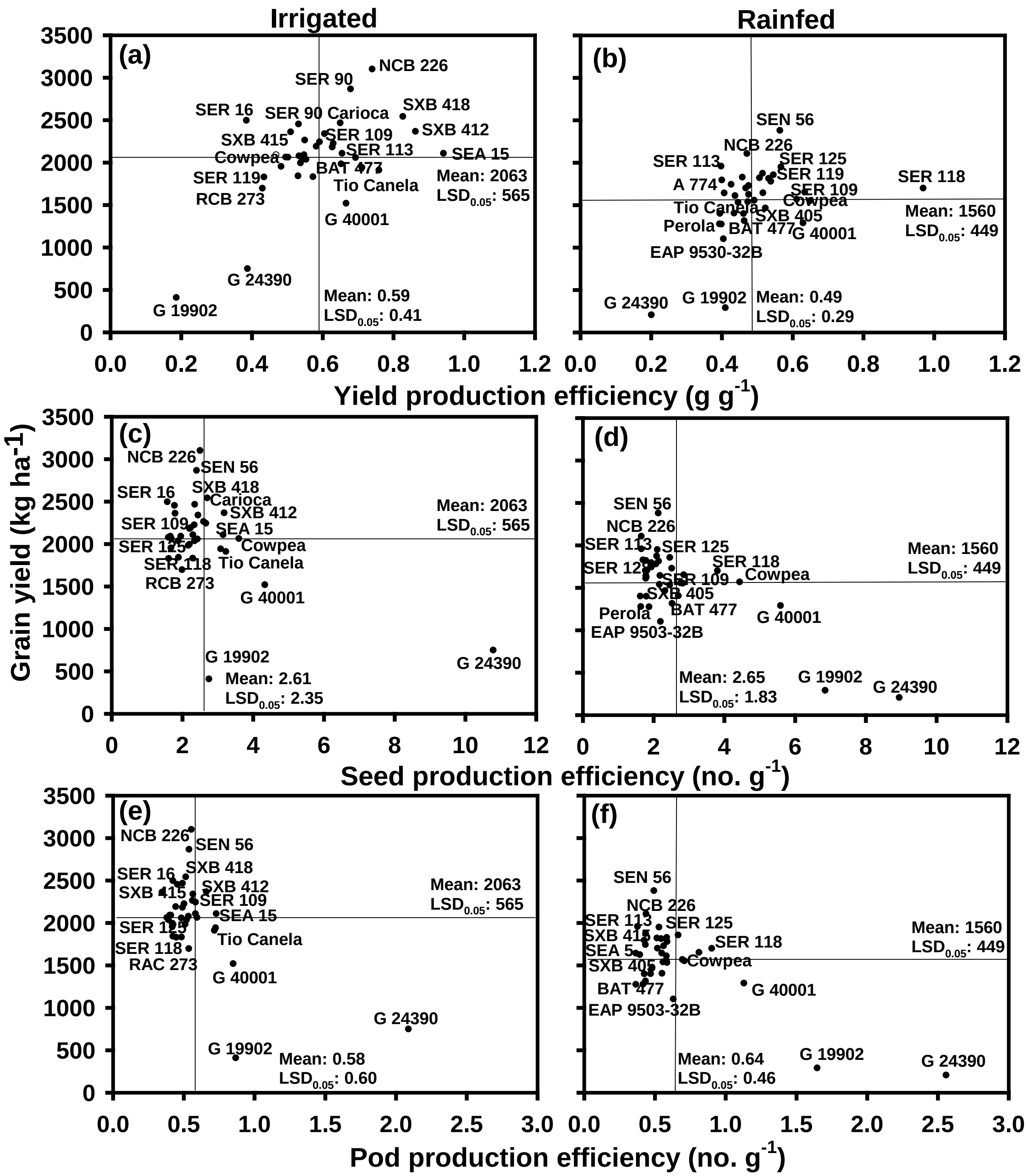

Figure 21. The relationship between grain yield and irrigated and rainfed yield production efficiency (a, b), grain yield and irrigated and rainfed seed production efficiency (c, d), and grain yield and irrigated and rainfed pod production efficiency (e, f) when grown in a Mollisol at Palmira.

Since a major role of transpiration is leaf cooling, canopy temperature depression (CTD) relative to ambient air temperature is an indication of how capable is transpiration in cooling the leaves under a demanding environmental load. Relatively lower canopy temperature under drought stress could indicate a relatively better capacity for taking up soil moisture and for maintaining a relatively better plant water status. But CTD can be a poor indicator of resistance to drought if grain yield is highly dependent on limited amounts of soil-stored water. Relationship between CTD (canopy and ambient temperature difference at 1 pm) with rainfed grain yield indicated that the lines SEN 56, NCB 226, SEA 5, Cowpea, Carioca, G19902 and G24390 showed higher values of CTD that indicate greater rates of transpirational water loss (Figure 22). However SEN 56 and NCB 226 combined higher values of CTD with higher grain yield under rainfed conditions while Carioca, G19902 and G24390 yielded less. Thus it is important to identify which genotypes are resisting drought by combining mechanisms such as photosynthate mobilization with efficient water use (e.g., SER lines including SER 118), and which genotypes are using deeper roots to maintain higher values of CTD but were not efficient in using water to produce greater seed yield under rainfed conditions (e.g., Carioca, G19902 and G24390).

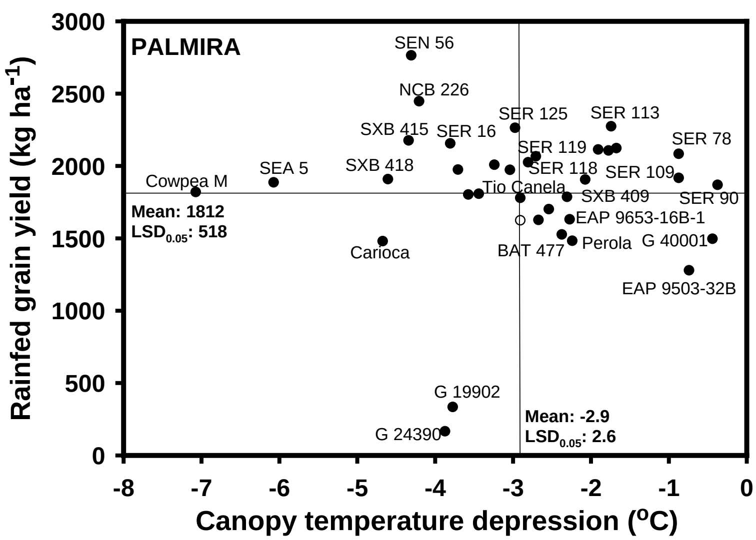

Figure 22. Identification of genotypes that combine superior seed yield with lower values of canopy temperature depression (CTD) when grown under rainfed conditions in a Mollisol at Palmira. Genotypes with greater seed yield and minimum differences were identified in the upper, right hand quadrant.

Among the 8 genotypes evaluated for root attributes, the line SER 16 and G24390 (Table 30) presented the higher values of total root production under rainfed conditions in terms of length while SEA 5 and G40001 presented the lowest production. Results on root distribution through soil profile showed that G24390, SEA 5 and Tio Canela 75 had developed deeper root system as revealed by the length and biomass of roots at 40-60 cm soil depth (Table 30). By comparing the root distribution data with CTD values, genotypes such as G24390, Tio Canela 75 and SEA 5 used deeper roots to cool the leaves, i.e., higher CTD values probably due to higher rates of transpiration. But lines such as SER 16 presented relatively less amount of roots and lower values of CTD with higher grain yield under drought conditions compared with the other genotypes. These results indicate that SER 16 was more water use efficient than G24390, Tio Canela 75 and SEA 5 due to its greater ability to mobilize photosynthates to grain. Further work is needed to verify these observations.

Table 30. Root attributes evaluated across soil depth of 8 bean elite lines grown under irrigated and rainfed conditions in a Mollisol in Palmira.

Genotype	Soil depth (cm)	Root length ($m\ m^{-3}$)		Root biomass ($g\ m^{-3}$)		Root diameter (mm)		Specific root length ($m\ g^{-1}$)	
		Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
DOR 390	0-5	3842	9658	33	136	0.25	0.28	110	77
	5-10	4799	9896	51	119	0.27	0.26	100	93
	10-20	2907	4894	25	48	0.25	0.26	114	102
	20-40	1669	805	21	12	0.30	0.33	80	69
	40-60	**1168**	**660**	**16**	**7**	**0.29**	**0.31**	**75**	**100**
G24390	0-5	4898	4564	31	28	0.25	0.26	156	143
	5-10	5912	12148	47	91	0.25	0.26	129	139
	10-20	3587	4436	25	41	0.25	0.29	142	105
	20-40	1532	2975	10	30	0.26	0.30	147	99
	40-60	**1478**	**1947**	**12**	**18**	**0.29**	**0.30**	**101**	**118**
G40001	0-5	2870	4265	35	28	0.27	0.26	77	169
	5-10	6037	10012	57	71	0.26	0.25	101	148
	10-20	4571	3841	46	40	0.27	0.27	101	96
	20-40	1445	1272	15	14	0.29	0.29	93	96
	40-60	**736**	**541**	**8**	**5**	**0.32**	**0.30**	**91**	**101**
SEA 5	0-5	7145	9056	72	98	0.28	0.29	99	86
	5-10	7071	5691	77	89	0.27	0.35	100	56
	10-20	3059	2912	37	39	0.30	0.29	77	82
	20-40	2007	2383	23	34	0.34	0.35	96	70
	40-60	**2162**	**2134**	**21**	**26**	**0.33**	**0.33**	**105**	**89**
SER 16	0-5	3239	8361	34	78	0.25	0.27	100	96
	5-10	8679	13573	72	132	0.25	0.26	121	104
	10-20	5003	3400	39	32	0.25	0.28	130	104
	20-40	866	1414	7	15	0.28	0.29	116	96
	40-60	690	1342	6	14	0.27	0.30	96	97
SER 109	0-5	4854	6342	47	60	0.26	0.26	102	101
	5-10	7222	9740	69	86	0.26	0.25	102	113
	10-20	4266	4554	37	49	0.26	0.27	111	96
	20-40	716	2413	7	29	0.29	0.29	104	84
	40-60	817	1645	7	17	0.30	0.29	105	89
SXB 418	0-5	2523	4234	27	40	0.32	0.27	92	106
	5-10	7391	9871	61	151	0.25	0.29	122	84
	10-20	4728	4588	50	64	0.27	0.29	89	78
	20-40	1626	2454	15	25	0.29	0.31	111	95
	40-60	1599	1565	14	16	0.28	0.31	124	93
Tío Canela 75	0-5	6551	5424	51	60	0.25	0.28	127	98
	5-10	8067	13356	63	137	0.24	0.27	134	101
	10-20	6400	3866	50	40	0.25	0.29	128	97
	20-40	2371	1629	21	15	0.30	0.28	113	115
	40-60	**935**	**1771**	**7**	**15**	**0.30**	**0.30**	**135**	**117**

Correlation coefficients between final grain yield and other shoot attributes under rainfed conditions indicated that greater seed yield was positively related to leaf area index, canopy biomass, harvest index, pod harvest index, stem biomass reduction, shoot and seed TNC content (Table 31). Significant negative correlations were observed between rainfed grain yield and seed production efficiency, pod production efficiency, days to flowering and days to maturity. These significant negative associations indicate that while earliness has contributed to superior performance under rainfed conditions, the formation of pods and seeds was not the factor limiting the grain yield. It was rather the ability to fill seeds as reflected by the significant positive associations between grain yield and harvest index, pod harvest index and 100 seed weight under rainfed conditions. Alternatively, the correlations were markedly influenced by including the two wild bean accessions that had greater values of pod and seed production efficiency per unit dry weight of shoot biomass.

Table 31. Correlation coefficients (r) between final grain yield (kg ha^{-1}) and other shoot attributes of elite lines grown under irrigated and rainfed conditions in a Mollisol in Palmira.

Plant traits	Irrigated	Rainfed
Leaf area index (m^2/m^2)	0.45***	0.25**
Total chlorophyll content (SPAD)	-0.01	0.01
Canopy biomass (kg ha^{-1})	0.48***	0.47***
Canopy temperature depression (°C)	-0.46***	-0.10
Shoot TNC content (mg g^{-1})	0.07	0.19*
Seed TNC content (mg g^{-1})	0.27**	0.23*
Pod partitioning index (%)	0.18	0.14
Harvest index (%)	0.23*	0.32**
Pod harvest index (%)	0.63***	0.71***
Yield production efficiency (g g^{-1})	0.23*	0.32**
Seed production efficiency (no. g^{-1})	-0.37***	-0.38***
Pod production efficiency (no. g^{-1})	-0.39***	-0.43***
Stem biomass reduction (%)	-0.01	0.30**
Days to flowering	-0.26**	-0.46***
Pod number per area (no. m^{-2})	0.006	-0.007
Seed number per area (no. m^{-2})	-0.004	0.04
Days to maturity	-0.29**	-0.34**
100 seed weight (g)	0.67***	0.68***
Grain filling index (%)		-0.18*

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Conclusions: Field evaluation of elite lines at Palmira resulted in identification of five lines NCB 226, SEN 56, SER 113, SER 125 and SER 16 that were outstanding in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of harvest index, pod harvest index, leaf area index and canopy biomass. In contrast, results on root growth and distribution under field conditions indicated that G24390, Tio Canela 75 and SEA 5 were more deep rooted than the drought adapted SER 16, suggesting that root growth in G24390 and Tio Canela 75 occurred at the expense of photosynthate mobilization to seed under drought stress. G19902 and G24390 were identified as the most poorly adapted to drought, suggesting that wild beans do not have inherent drought resistance, and that domestication has improved this trait. The SER lines that were developed in the last few years seem to combine the desirable traits for drought adaptation such as greater mobilization of photosynthates to seed with efficient use of water through stomatal control.

Contributors: J. Polanía, M. Grajales, C. Cajiao, R. García, J. Ricaurte, S. Beebe and I. M. Rao

2.1.1.8 Physiological evaluation of drought resistance of 33 recombinant inbred lines (RILs) of DOR 364 x BAT 477 under terminal drought stress over two seasons

Rationale: The bred line BAT 477 is very well adapted to drought while DOR 364 is a commercial variety in Central America and is less adapted to drought stress. We evaluated drought adaptation of 33 RILs of the cross DOR 364 x BAT 477 over two seasons to obtain phenotypic data for eventual gene tagging for drought resistance.

Materials and Methods: Two field trials were conducted at Palmira in 2005 (June to September) and 2006 (June to September). The two trials included 97 RILs of DOR 364 x BAT 477 along with 1 check (SEA 5) and 2 parents (DOR 364, BAT 477) but only 33 RILs were selected for intensive characterization to determine genotypic differences in tolerance to drought stress conditions. A 10 x 10 balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. For the irrigated treatment, a total of 5 gravity irrigations were applied while for the rainfed treatment only 2 irrigations (approximately 35 mm each) in 2005 and 3 in 2006 were applied to assure good crop establishment. Details on planting and management of the trial were similar to those reported before. Experimental units consisted of 2 rows, 3.72 m long by 0.6 m wide. A number of plant attributes were measured at mid-pod filling only under rainfed conditions in 2005 and under both conditions in 2006 in order to determine genotypic variation in drought resistance. These plant traits included leaf chlorophyll content (SPAD); leaf area index; canopy dry weight per plant; shoot nutrient (N, P) uptake; shoot and seed ash content; and shoot and seed TNC (total nonstructural carbohydrates). At the time of harvest, grain yield and yield components (number of pods per plant, number of seeds per pod, and 100 seed weight) were determined. Stem biomass reduction (mobilization of photosynthate reserves) was determined based on difference in stem dry weight at harvest from the stem dry weight at mid-pod filling. Pod partitioning index (dry wt of pods at harvest/dry wt of total biomass at mid-podfill x 100), pod number per area, seed number per area, pod harvest index (dry wt of seed/dry wt of pod at harvest x 100), yield production efficiency (seed biomass dry weight at harvest/total shoot biomass dry weight at mid-pod filling), seed production efficiency (seed number per area/ total shoot biomass dry weight at mid-pod filling per area), pod production efficiency (pod number per area/ total shoot biomass dry weight at mid-pod filling per area) and grain filling index (100 seed weight of rainfed/100 seed weight of irrigated) were determined. Seed P content, ash content and TNC (total nonstructural carbohydrate) content were also measured.

Results and Discussion: *Palmira – Soil, temperature, rainfall and evaporation:* The soil is a Mollisol (Aquic Hapludoll) with no major fertility problems (pH = 7.7), and is estimated to permit storage of 130 mm of available water (assuming 1.0 m of effective root growth with –0.03 MPa and –1.5 MPa upper and lower limits for soil matric potential). During the crop-growing season, maximum and minimum air temperatures were 34.5 and 15.8 °C in 2005 and 34.2 and 16 ^{o}C in 2006 (Figure 23). The incident solar radiation ranged from 10.2 to 22.8 MJ m^{-2} d^{-1} in 2005 and 9.2 to 23.9 MJ m^{-2} d^{-1} in 2006. The total rainfall during the active crop growth was 126.4 mm in 2005 (most of which fell at the end of the crop growing season) and 33.2 in 2006. The potential pan evaporation was of 400.5 mm in 2005 and 410.7 in 2006. These data on rainfall and pan evaporation together with rainfall distribution indicated that the crop suffered significant terminal drought stress during active growth and development in both years. The mean yield under rainfed conditions was 723 kg ha^{-1} compared with the mean irrigated yield of 1655 kg ha^{-1} (56% decrease in grain yield due to drought stress).

Under drought stress conditions in the field, the seed yield of 33 RILs ranged from 537 to 1029 kg ha^{-1} (Figure 24). Among the RILs tested, two RILs BT 21138-17-1-1 and BT 21138-6-1-1 were outstanding in their adaptation to rainfed (water stress) conditions. The relationship between grain yield of rainfed and irrigated treatments indicated that several RILs were superior to the best parent, BAT 477 and the check genotype, SEA 5. Among the 33 lines tested, BT 21138-31-1-1 and BT 21138-28-1-1 were found to be very poorly adapted RILs under rainfed conditions.

Significant genotypic differences were observed in canopy biomass production at mid-pod filling growth stage (Figure 24). The RILs BT 21138-30-1-1, BT 21138-3-1-1 and BT 21138-83-1-1 showed greater vigor than the rest of the RILs; however these RILs showed lower value of harvest index indicating a limitation on mobilization of photosynthates to pod and seed development. The two RILs BT 21138-17-1-1 and BT 21138-6-1-1 with moderate values of canopy biomass (Figure 24) yielded well under rainfed conditions due to greater ability to partition photosynthetically assimilated carbon to pods as reflected by higher values of harvest index (Figure 24). The relationship between rainfed seed yield and other plant attributes indicated that the outstanding performance of lines BT 21138-17-1-1 and BT 21138-6-1-1 was associated with higher values of pod harvest index (Figure 24) indicating greater mobilization of photosynthates to the grain.

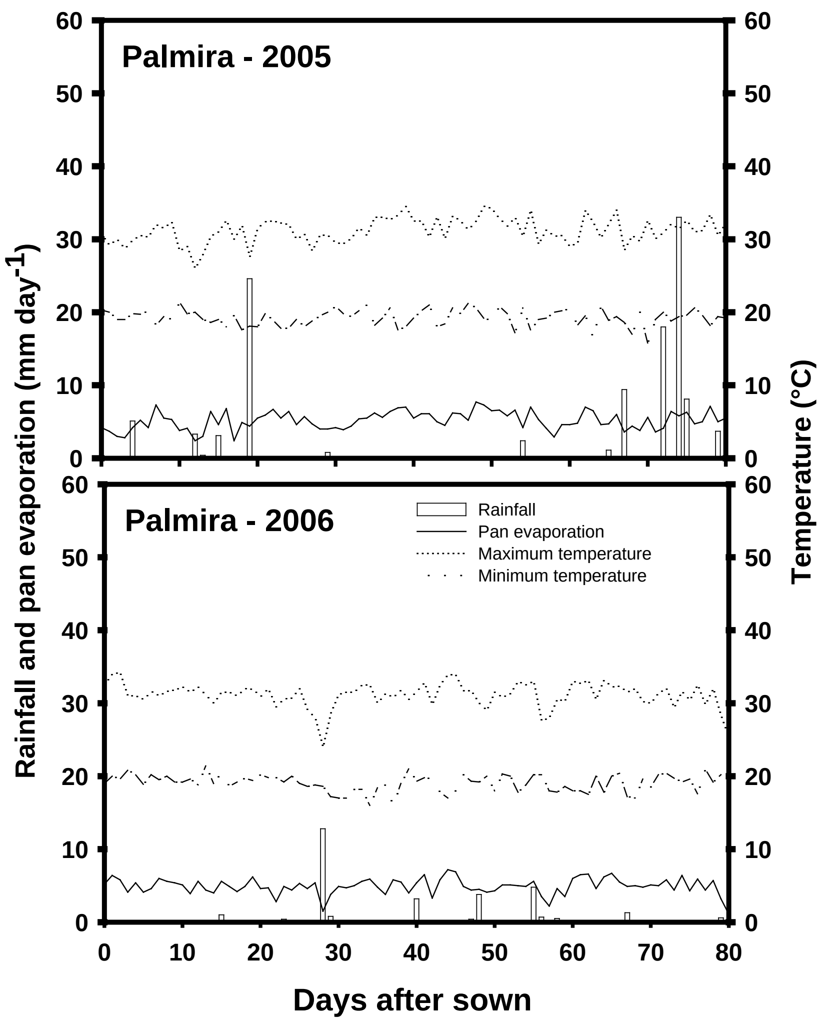

Figure 23. Rainfall distribution, pan evaporation, maximum and minimum temperatures during crop growing period at Palmira in 2005 and 2006.

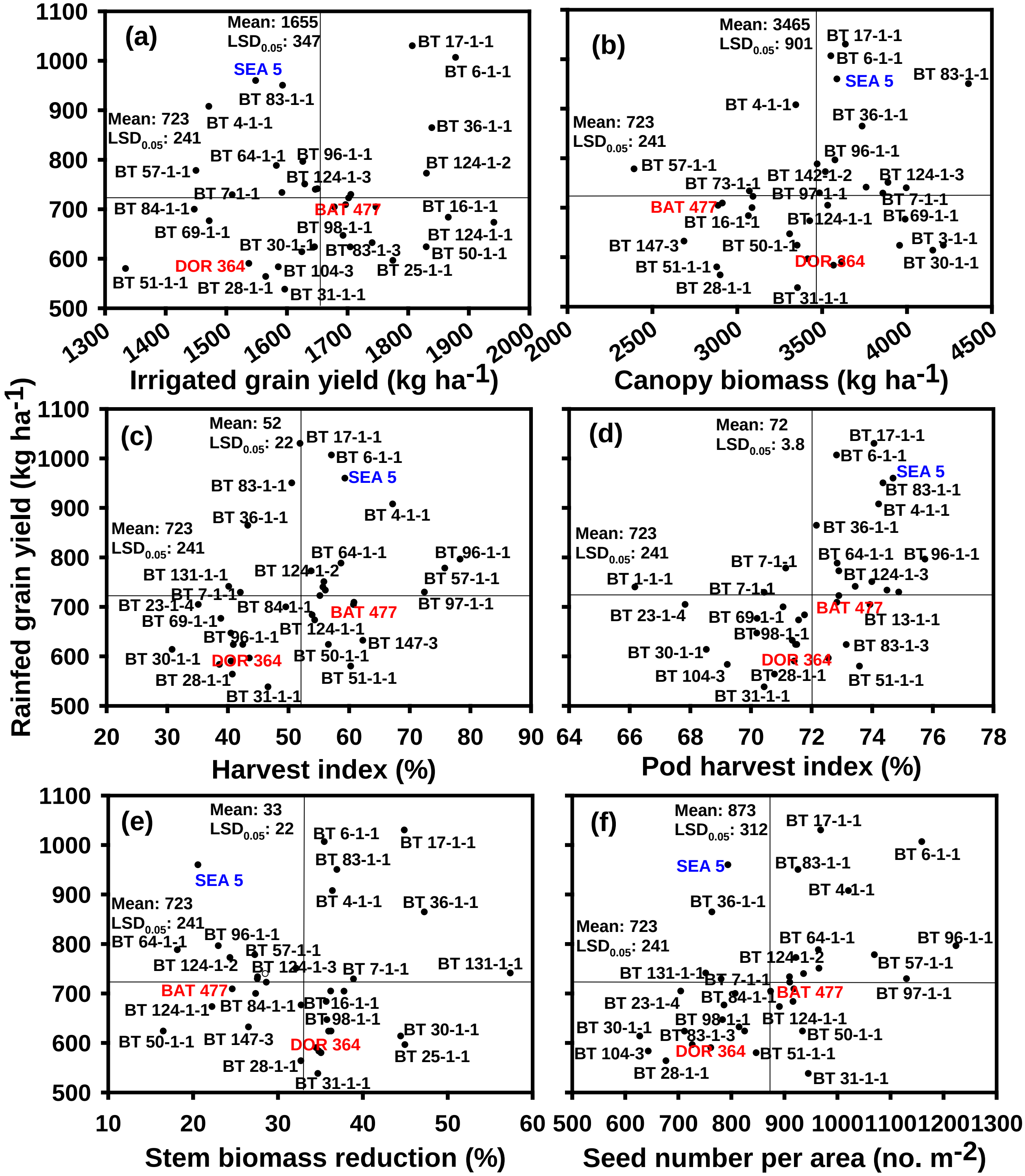

Figure 24. Identification of genotypes that are (a) adapted to rainfed conditions and are responsive to irrigation; and combine higher values of rainfed grain yield with superior values of (b) canopy biomass, (c) harvest index, (d) pod harvest index, (e) stem biomass reduction, and (f) seed number per area

Correlation coefficients between final grain yield and other shoot attributes under rainfed conditions indicated significant negative relationship between seed yield and total chlorophyll content and seed N and P content under rainfed conditions (Table 32). This observation indicates that genotypes that mobilized greater amounts of N and P together with photosynthates yielded better under rainfed conditions. It is important to note that the pod harvest index was significantly associated with seed yield under rainfed conditions. This indicates that the genotypes that mobilized a greater proportion of photosyntates from pod to seed performed better under rainfed conditions (Figure 24). Significant positive associations were also observed between rainfed grain yield and seed number per area, pod number per area, yield production efficiency, seed production efficiency and pod production efficiency indicating the contribution of improved plant efficiency under drought stress to produce grain. However reduction in stem biomass showed no significant correlation with rainfed grain yield and this may be due to the late rains in 2005 season that might have allowed some lines to grow during seed filling.

Table 32. Correlation coefficients (r) between final grain yield (kg ha^{-1}) and other plant attributes of RILs of common bean grown under rainfed conditions in a Mollisol in Palmira.

Plant traits	**Rainfed**
Leaf area index (m^{2} m^{-2})	0.16*
Total chlorophyll content (SPAD)	-0.41***
Canopy biomass (kg ha^{-1})	0.26***
Seed TNC Content (mg g^{-1})	-0.11
Seed N Content (%)	-0.42***
Seed P Content (%)	-0.31***
Pod partitioning index (%)	0.40***
Pod harvest index (%)	0.43***
Harvest index (%)	0.41***
Seed number per area (no. m^{-2})	0.56***
Pod number per area (no. m^{-2})	0.45***
Yield production efficiency (g g^{-1})	0.41***
Seed production efficiency (no. g^{-1})	0.41***
Pod production efficiency (no. g^{-1})	0.27***
Stem biomass reduction (%)	-0.12

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Conclusions: Field evaluation of 33 RILs of the cross DOR 364 x BAT 477 at Palmira over two seasons under terminal drought stress conditions resulted in identification of two lines (BT 21138-17-1-1 and BT 21138-6-1-1) that were superior in their adaptation to drought stress conditions. The superior performance of these lines under drought stress was associated with higher values of harvest index, pod harvest index and seed and pod number per area indicating the importance of greater mobilization of photosyntates to pods and to seeds under rainfed conditions.

Contributors: J. Polanía, M. Grajales, C. Cajiao, R. García, J. Ricaurte, S. Beebe and I. M. Rao

2.1.1.9 Physiological evaluation of drought resistance in recombinant inbred lines (RILs) of DOR 364 x BAT 477 under intermittent drought stress

Rationale: We evaluated drought adaptation of 33 RILs of the cross DOR 364 x BAT 477 over two seasons (2005 and 2006) under terminal drought stress. In 2007, we evaluated 97 RILs of the cross DOR 364 x BAT 477 under intermittent drought stress to obtain phenotypic data for eventual gene tagging for drought resistance.

Materials and Methods: A field trial was conducted at Palmira in 2007 (June to September). The soil is a Mollisol (Aquic Hapludoll) with no major fertility problems (pH = 7.7), and is estimated to permit storage of 130 mm of available water (assuming 1.0 m of effective root growth with –0.03 MPa and –1.5 MPa upper and lower limits for soil matric potential). The trial included 97 RILs of DOR 364 x BAT 477 along with 1 check (SEA 5) and 2 parents (DOR 364, BAT 477) to determine genotypic differences in tolerance to drought stress conditions. A 10 x 10 balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. For the irrigated treatment, a total of 4 gravity irrigations (approximately 35 mm each) were applied while for the rainfed treatment only 2 irrigations were applied to assure good crop establishment. Experimental units consisted of 2 rows, 3.72 m long by 0.6 m wide. A number of plant attributes were measured at mid-podfilling under both rainfed and irrigated conditions in order to determine genotypic variation in drought resistance. These plant traits included leaf chlorophyll content (SPAD), canopy temperature, canopy temperature depression (CTD), leaf area index, canopy dry weight per plant and shoot TNC content (total nonstructural carbohydrates).

Canopy temperature was measured with a Telatemp model AG-42D infrared thermometer. The instrument was held at a 45^o angle at 50 cm from the canopy surface to measure canopy temperature and canopy temperature depression. At the time of harvest, grain yield and yield components (number of pods per plant, number of seeds per pod, and 100 seed weight) were determined. Stem biomass reduction (mobilization of photosynthate reserves) was determined based on difference in stem dry weight at harvest from the stem dry weight at mid-pod filling. Pod partitioning index (dry wt of pods at harvest/dry wt of total biomass at mid-podfill x 100), pod harvest index (dry wt of seed/dry wt of pod at harvest x 100), pod number per area, seed number per area, yield production efficiency (seed biomass dry weight at harvest/total shoot biomass dry weight at mid-pod filling), seed production efficiency (seed number per area/ total shoot biomass dry weight at mid-pod filling per area), pod production efficiency (pod number per area/ total shoot biomass dry weight at mid-pod filling per area) and grain filling index (100 seed weight of rainfed/100 seed weight of irrigated) were determined. Shoot and seed TNC (total nonstructural carbohydrate) contents were also measured.

Results and Discussion: During the crop-growing season, maximum and minimum air temperatures were 30.56 and 18.61 ^{o}C (Figure 25). The incident solar radiation ranged from 11.2 to 25.1 MJ m^{-2} d^{-1}. The total rainfall during the active crop growth was 243.1 mm (a significant portion falling during grainfilling). The potential pan evaporation was of 431 mm. These data on rainfall and pan evaporation together with rainfall distribution indicated that the crop suffered intermittent drought stress during active growth and development. The mean yield under rainfed conditions was 849 kg ha^{-1} compared with the mean irrigated yield of 1741 kg ha^{-1} showing 51% decrease in mean grain yield due to drought stress (Figure 26).

Under drought stress conditions in the field, the seed yield of 97 RILs ranged from 603 to 1171 kg ha^{-1} (Figure 26). Among the RILs tested, two RILs BT 21138-68-1-1 and BT 21138-74-1-1 were outstanding in their adaptation to rainfed (water stress) conditions. The relationship between grain yield of rainfed and irrigated treatments indicated that several RILs were superior to the best parent, BAT 477 and the check genotype, SEA 5. Among the 97 lines tested, BT 21138-31-1-1 and BT 21138-34-1-1 were found to be very poorly adapted lines under rainfed conditions.

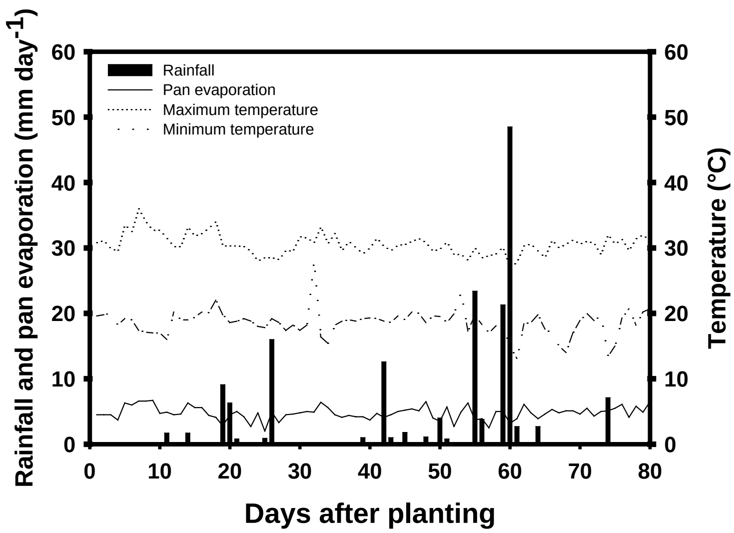

Figure 25. Rainfall distribution, pan evaporation, maximum and minimum temperatures during crop growing period at Palmira in 2007.

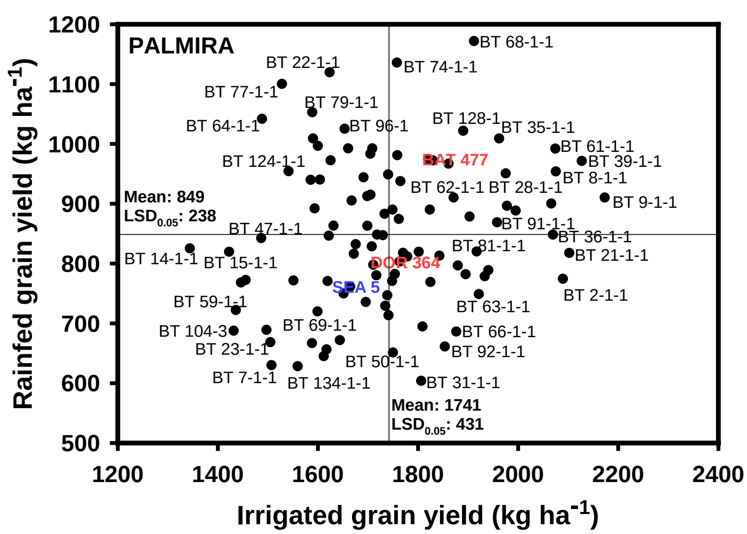

Figure 26. Identification of genotypes that are adapted to rainfed conditions and are responsive to irrigation in a Mollisol at Palmira. Genotypes that yield superior with drought and were also responsive to irrigation were identified in the upper, right hand quadrant.

Significant genotypic differences were observed in canopy biomass production at mid-pod filling growth stage (Figure 27). The RILs BT 21138-64-1-1 and BT 21138-69-1-1 showed greater vigor than the rest of the RILs; however these RILs showed lower value of harvest index indicating a limitation on mobilization of photosynthates to pod and seed development. The relationship between rainfed seed yield and other plant attributes showed that the outstanding performance of lines BT 21138-68-1-1 and BT 21138-74-1-1 was associated with higher values of stem biomass reduction indicating greater mobilization of photosynthates from stems to pods (Figure 28).

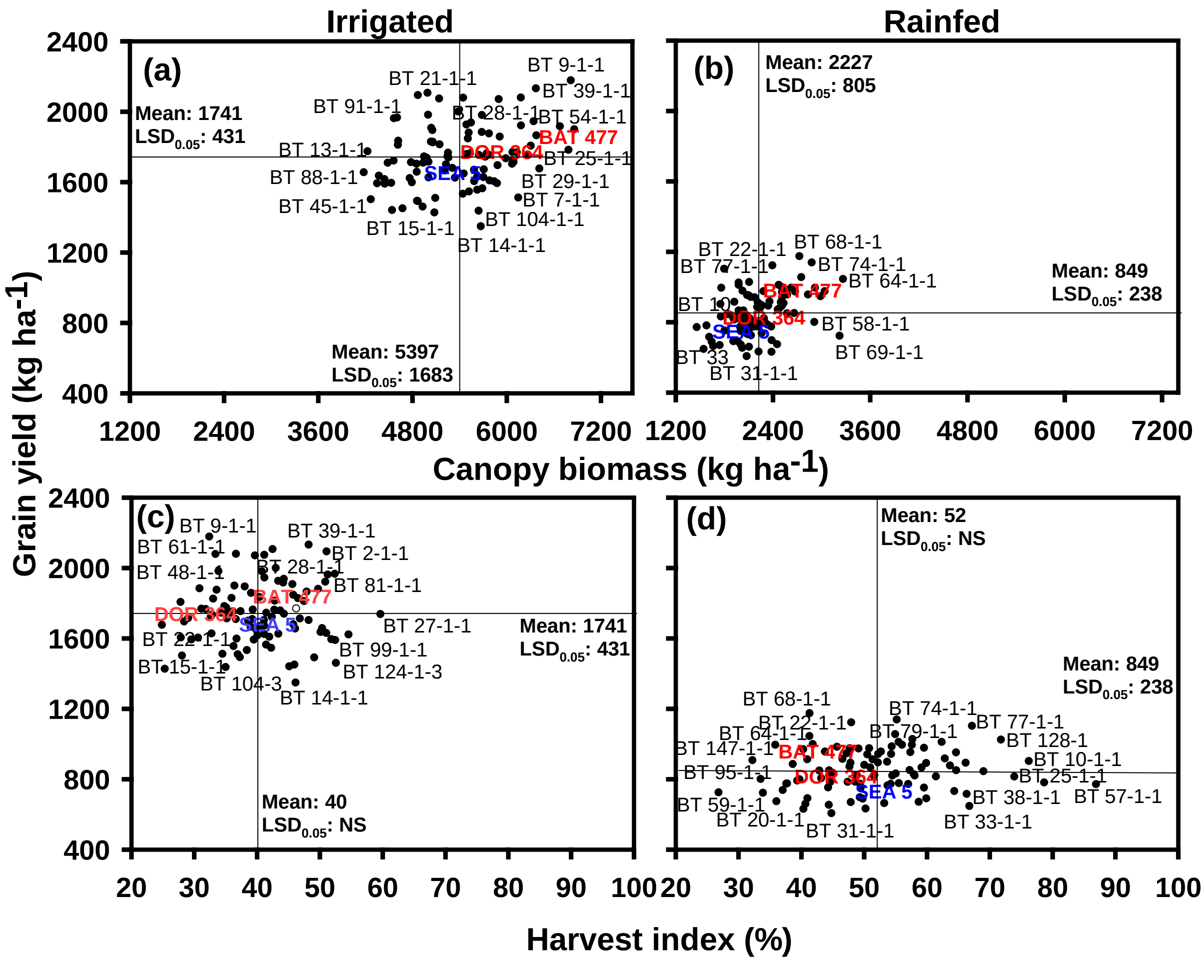

Figure 27. The relationship between grain yield and irrigated and rainfed canopy biomass (a, b) and grain yield and irrigated and rainfed harvest index (c, d) when grown in a Mollisol at Palmira.

The relationship between rainfed seed yield and seed number per area, pod number per area and 100 seed weight showed that the line BT 21138-74-1-1 was outstanding in producing greater number of seeds and pods and also in filling the grain (Figure 29).

Correlation coefficients between final grain yield and other shoot attributes under rainfed conditions indicated significant relationship between seed yield and leaf area index and canopy biomass under irrigated and rainfed conditions (Table 33). It is important to note that the harvest index, pod partitioning index, pod harvest index, seed number per area and pod number per area showed significant positive association with seed yield under rainfed conditions. This indicates that the genotypes that mobilized a greater proportion of photosyntates from plant structures to pod and seed formation performed better under rainfed conditions (Figures 28 and 29).

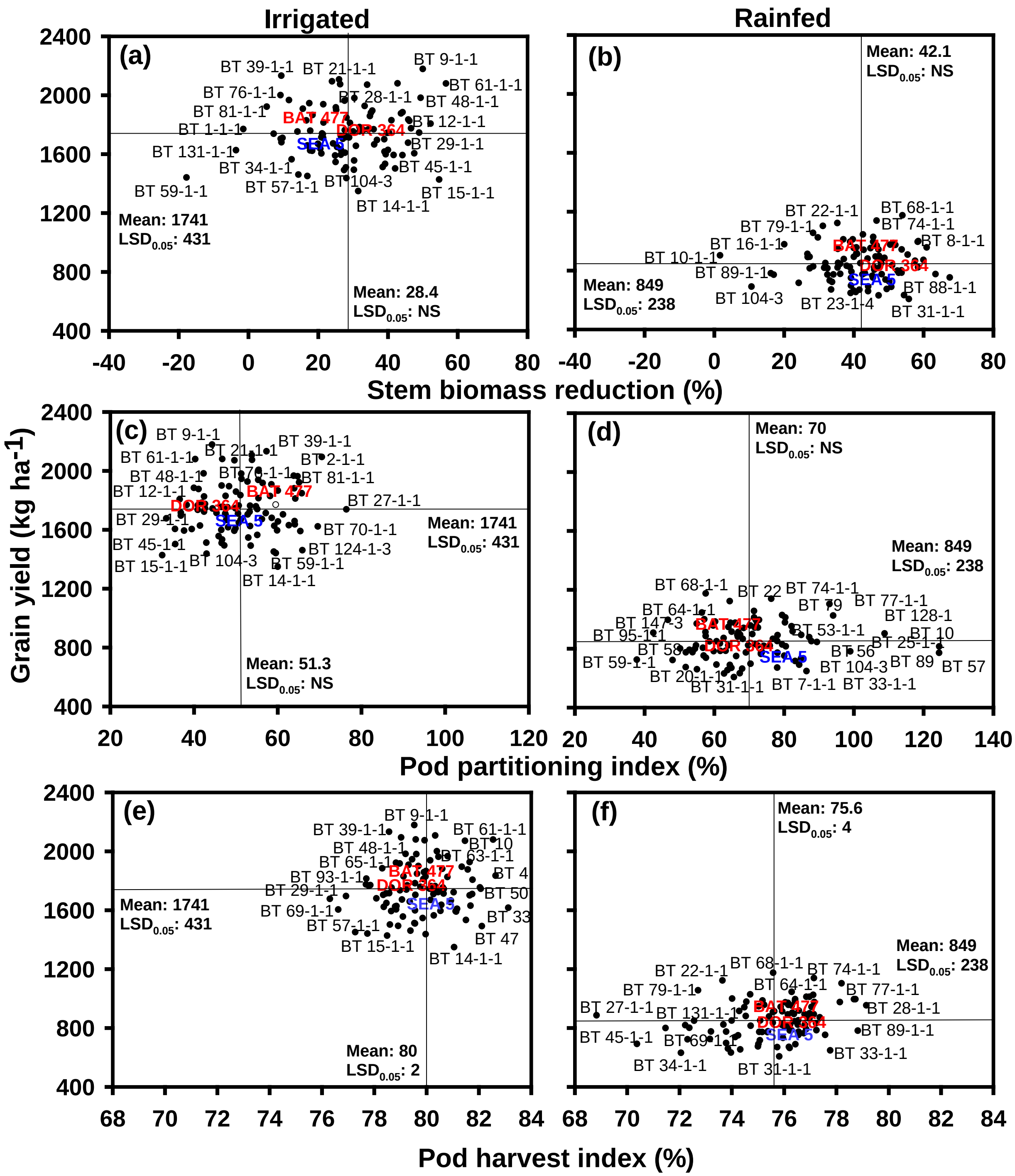

Figure 28. The relationship between grain yield and irrigated and rainfed stem biomass reduction (a, b), grain yield and irrigated and rainfed pod partitioning index (c, d), and grain yield and irrigated and rainfed pod partitioning index (e, f) when grown in a Mollisol at Palmira.

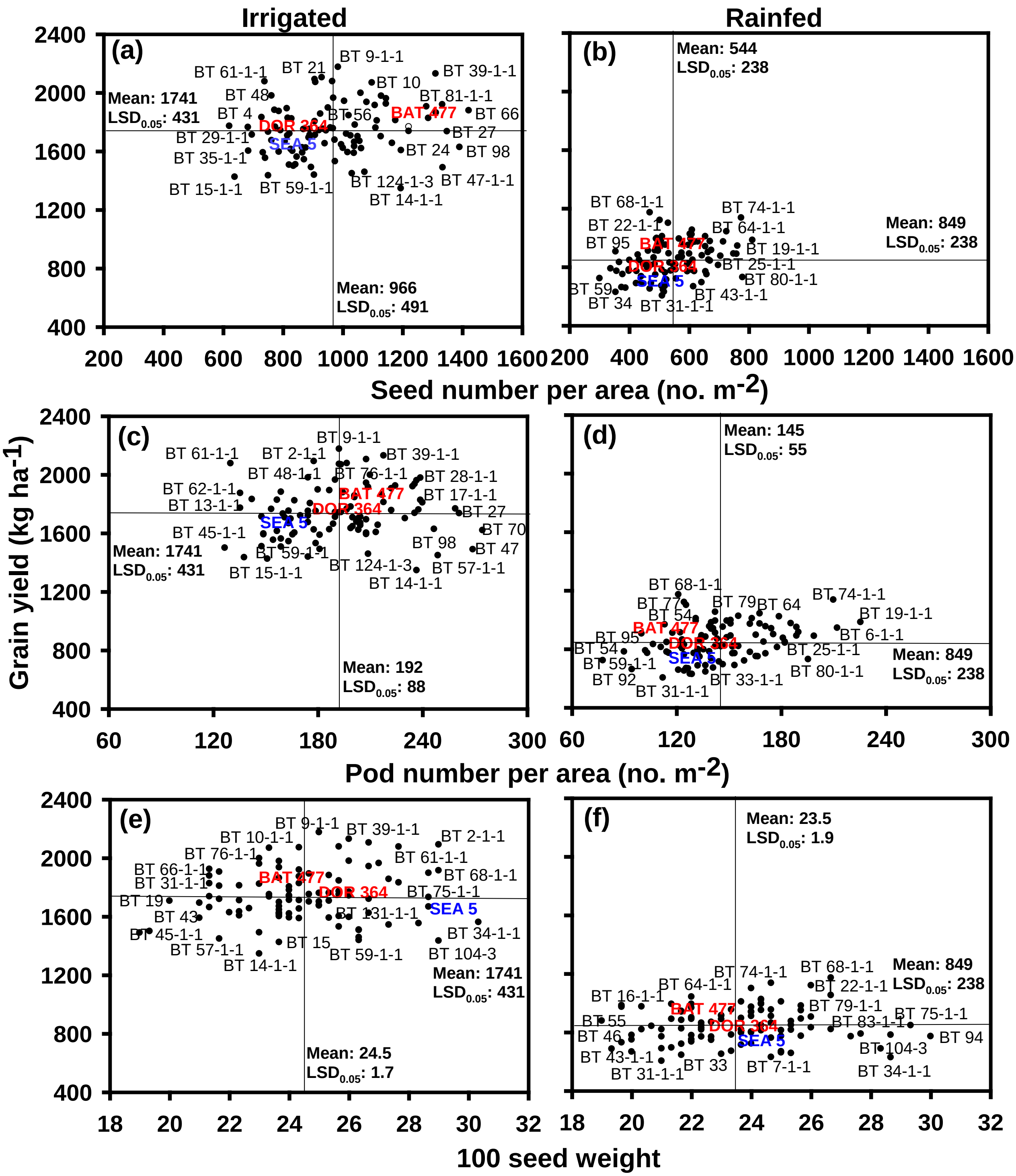

Figure 29. The relationship between grain yield and irrigated and rainfed seed number per area (a, b), grain yield and irrigated and rainfed pod number per area (c, d), and grain yield and irrigated and rainfed 100 seed weight (e, f) when grown in a Mollisol at Palmira.

Table 33. Correlation coefficients (r) between final grain yield (kg/ha) and other plant attributes of RILs of common bean grown under irrigated and rainfed conditions in a Mollisol in Palmira.

Plant traits	Irrigated	Rainfed
Leaf area index (m^2/m^2)	0.19***	0.34**
Total chlorophyll content (SPAD)	-0.12*	0.12*
Canopy biomass (kg ha^{-1})	0.38***	0.33***
Canopy temperature (^oC)	-0.13*	-0.08
Canopy temperature depression (^oC)	-0.16**	-0.09
Shoot TNC content (mg g^{-1})	0.10	-0.02
Seed TNC content (mg g^{-1})	-0.09	-0.02
Pod partitioning index (%)	0.02	0.11*
Harvest index (%)	0.03	0.13*
Pod harvest index (%)	0.11*	0.19***
Stem biomass reduction (%)	0.04	-0.10
Seed number per area (No m^2)	0.23***	0.35***
Pod number per area (No m^2)	0.12*	0.31***
Seed number per pod	0.17**	0.13*
Days to flowering	0.07	-0.05
Days to maturity	0.14*	0.08
100 seed weight (g)	0.11*	0.11*
Grain filling index (%)		0.12*

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Conclusions: Field evaluation of 97 RILs of the cross DOR 364 x BAT 477 under intermittent drought stress resulted in identification of two RILs BT 21138-68-1-1 and BT 21138-74-1-1 that were outstanding in adaptation to intermittent drought stress conditions. The superior performance of these lines under intermittent drought stress was associated with higher values of harvest index, pod partitioning index, stem biomass reduction, seed number per area and pod number per area indicating the importance of greater mobilization of photosyntates to pods and seeds under rainfed conditions.

Contributors: J. Polanía, M. Grajales, C. Cajiao, R. García, J. Ricaurte, S. Beebe and I. M. Rao

2.1.1.10 Evaluation of drought resistance in recombinant inbred lines (RILs) of MD 23-24 x SEA 5 under intermittent drought stress

Rationale: We evaluated drought adaptation of 121 RILs of the cross MD 23-24 x SEA 5 over three seasons to obtain phenotypic data for eventual gene tagging. The bred line SEA 5 is very well adapted to drought while MD 23-24 is superior in commercial grain quality. The mean results over three seasons are reported.

Materials and Methods: Three field trials were conducted at Palmira in 2003, 2004 and 2007 (June to September). The soil is a Mollisol (Aquic Hapludoll) with no major fertility problems (pH = 7.7), and is estimated to permit storage of 130 mm of available water (assuming 1.0 m of effective root growth with –0.03 MPa and –1.5 MPa upper and lower limits for soil matric potential). The trials included 121 RILs of MD 23-24 x SEA 5 along with 5 checks (Cowpea, Tio Canela 75, DOR 390, EAP 9510-77 and SEA 15) and 2 parents (MD 23-24, SEA 5) to determine genotypic differences in tolerance to drought stress conditions**.** An 11 x 11 balanced lattice design with 3 replicates was used. Two levels of water supply (irrigated and rainfed) were applied. Details on planting and management of the trial were similar to those reported before. Experimental units consisted of 2 rows, 3.72 m long by 0.6 m wide. A number of plant attributes were measured at mid-podfilling in order to determine genotypic variation in drought resistance. These plant traits included leaf chlorophyll content (SPAD), leaf area index; canopy dry weight per plant; shoot and seed ash content; and shoot and seed TNC (total nonstructural carbohydrates). At the time of harvest, grain yield and yield components (number of pods per plant, number of seeds per pod, 100 seed weight) were determined. Seed ash content and TNC (total nonstructural carbohydrates) were measure. Pod harvest index (seed weight/pod weight x 100) and grain filling index (100 seed weight of rainfed/100 seed weight of irrigated x 100) were also measured.

Results and Discussion: During the crop-growing season, maximum and minimum air temperatures in 2003 were 33 and 14.6 °C, in 2004 were, 34.4 and 15.6 °C and in 2007 were, 30.5 and 18.6 °C, respectively (Figure 30). The incident solar radiation ranged from 8.2 to 23.3 MJ m^{-2} d^{-1} in 2003, 10.3 to 22.7 MJ m^{-2} d^{-1} in 2004 and 11.2 to 25.1 MJ m^{-2} d^{-1} in 2007. The total rainfall during the active crop growth was 126.5 mm in 2003, 110.4 mm in 2004 and 243.1 mm (a significant proportion of which fell during seed filling) in 2007. The potential pan evaporation was of 363 mm in 2003, 390 mm in 2004 and 431 mm in 2007. These data on rainfall and pan evaporation together with rainfall distribution indicated that the crop suffered intermittent drought during active growth and development. The mean yield under rainfed conditions was 1182 kg ha^{-1} compared with the mean irrigated yield of 1846 kg ha^{-1} with about 36% reduction of mean grain yield under drought stress (Figure 31).

Under drought stress conditions in the field, the seed yield of 121 RILs ranged from 690 to 1574 kg ha^{-1} (Figure 31). Among the lines tested, three RILs, MR 81, MR 112 and MR 25 were outstanding in their adaptation to rainfed (water stress) conditions. These three lines were also responsive to irrigation. The relationship between grain yield of rainfed and irrigated treatments indicated that several RILs lines were superior to the best parent, SEA 5 and the 4 common bean check genotypes. Among the 121 lines tested, MR 8 was the most poorly adapted line under rainfed conditions.

High significant correlation was observed between canopy biomass and grain yield; the genotype Cowpea Mouride showed the highest vigor with the highest canopy biomass under stress conditions (Figure 32). But this genotype showed a lower harvest index, indicating its limitation to mobilize photosyntates to seeds. Results on the relationship between rainfed grain yield and harvest index (HI) indicated that MR 25 and MR 81 were superior in mobilizing photosyntates to seeds (Figure 32). The HI value of EAP 9510-77, MR 109 and MR 40 was markedly lower than that of other bean genotypes. Results on the relationship between rainfed grain yield and pod harvest index indicated that MR 81 and MR 25 were superior in mobilizing photosyntates from pod to seeds (Figure 33).

The superior performance of RILs MR25 and MR 81 was associated with greater values of harvest index, higher values of pod harvest index and seed number per area, higher values of stem biomass reduction (Figure 33). Higher stem biomass reduction values indicate higher photosyntates mobilization from the stem to other plant structures such as pods.

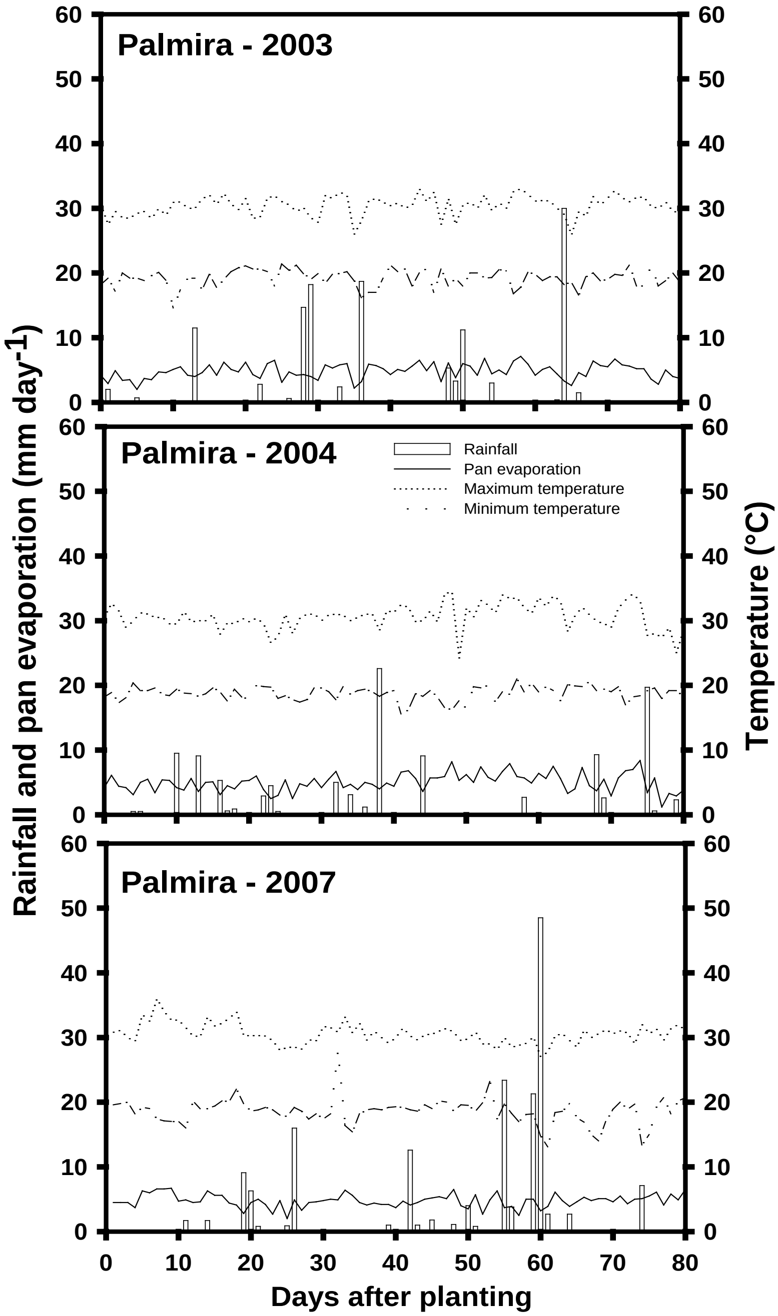

Figure 30. Rainfall distribution, pan evaporation, maximum and minimum temperatures during crop growing period at Palmira during 2003, 2004 and 2007 crop growing seasons.

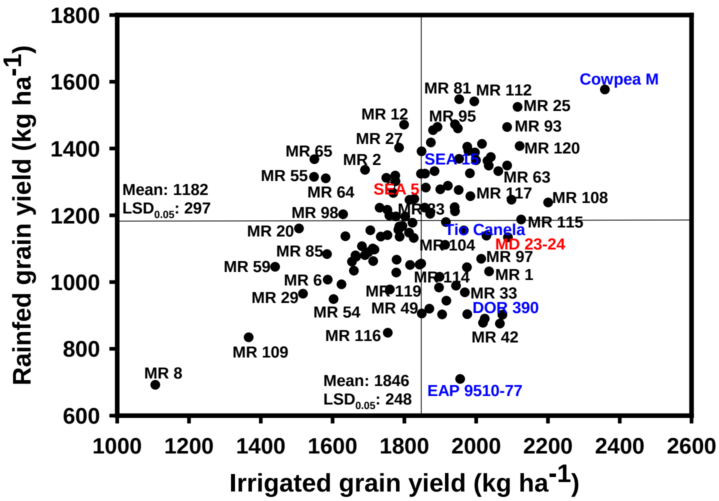

Figure 31. Identification of genotypes that are adapted to rainfed conditions and are responsive to irrigation in a Mollisol at Palmira. Genotypes that yield superior with drought and were also responsive to irrigation were identified in the upper, right hand quadrant

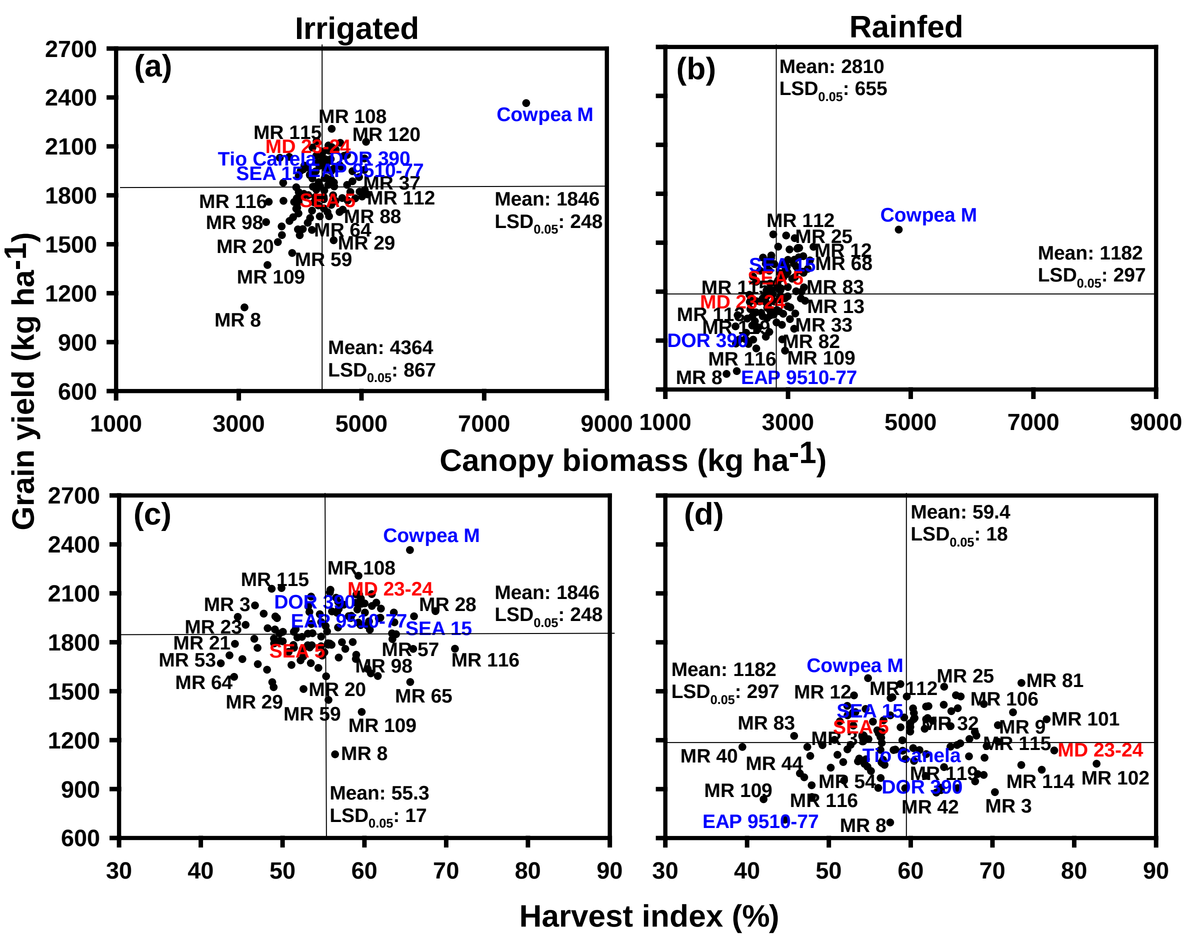

Figure 32. The relationship between grain yield and irrigated and rainfed canopy biomass (a, b) and grain yield and irrigated and rainfed harvest index (c, d) when grown in a Mollisol at Palmira

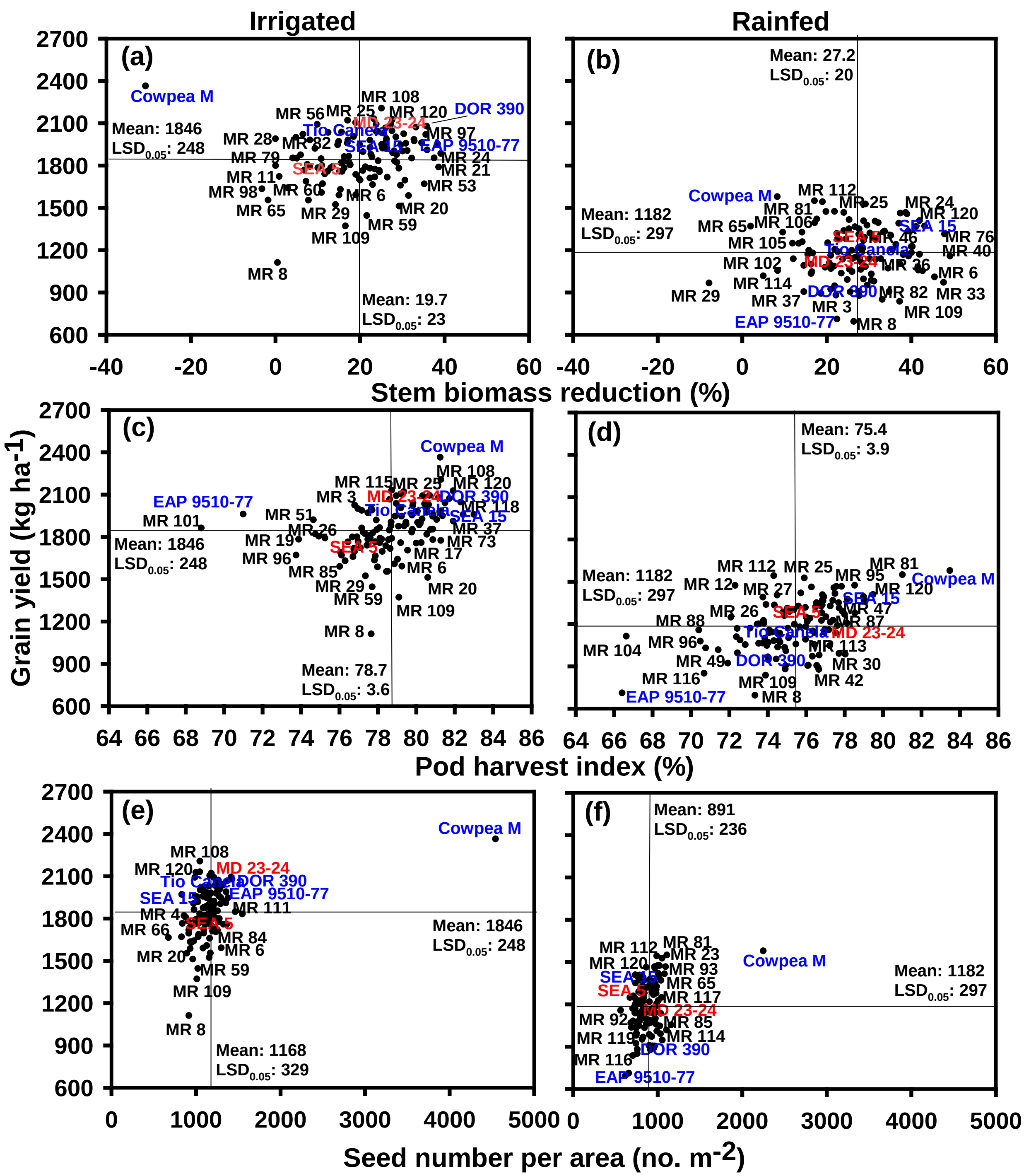

Figure 33. The relationship between grain yield and irrigated and rainfed stem biomass reduction (a, b), grain yield and irrigated and rainfed pod harvest index (c, d), and grain yield and irrigated and rainfed seed number per area (e, f) when grown in a Mollisol at Palmira.

Correlation coefficients between final grain yield and other shoot attributes under rainfed conditions indicated significant positive relationship between final grain yield and leaf area index and canopy biomass under rainfed conditions (Table 34). Total chlorophyll content showed positive relationship with grain yield under irrigated conditions. It is important to note that the harvest index, pod partitioning index and pod harvest index were significantly associated with grain yield under rainfed conditions. This indicates that the genotypes that mobilized a greater proportion of photosyntates from vegetative organs to developing grains performed better under rainfed conditions (Figure 33). Seed number per area and pod number per area also showed significant positive association with grain yield only under rainfed conditions. Pod production efficiency showed significant negative association with grain yield under both irrigated and rainfed conditions. Days to maturity also showed significant negative association with grain yield indicating some contribution of earliness to superior performance under rainfed conditions.

Table 34. Correlation coefficients (r) between final grain yield (kg ha^{-1}) and other plant attributes of RILs of common bean grown under irrigated and rainfed conditions in a Mollisol in Palmira

Plant traits	Irrigated	Rainfed
Leaf area index (m^2/m^2)	-0.10**	0.39***
Total chlorophyll content (SPAD)	0.15***	-0.001
Canopy biomass (kg ha^{-1})	0.38***	0.45***
Shoot TNC content (mg g^{-1})	0.08	-0.11**
Seed TNC content (mg g^{-1})	0.18***	0.02
Pod partitioning index (%)	-0.14***	0.07
Pod harvest index (%)	0.08	0.37***
Stem biomass reduction (%)	0.03	0.11***
Seed number per area (no. m^2)	0.05	0.34***
Pod number per area (no. m^2)	-0.03	0.15***
Harvest index (%)	-0.12***	0.13***
Yield production efficiency (g g^{-1})	-0.12***	0.13***
Seed production efficiency (no. g^{-1})	-0.25***	-0.03
Pod production efficiency (no. g^{-1})	-0.32***	-0.26***
Days to maturity	0.45***	-0.16***
100 seed weight (g)	0.17***	0.11**

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.

Conclusions: Field evaluation of 121 RILs of the cross MD 23-24 x SEA 5 over 3 seasons resulted in identification of the lines MR 81 and MR 25 that were superior in adaptation to drought stress conditions. The superior performance of these lines was associated with higher vigor, higher values of pod harvest index, harvest index and seed number per area, highlighting the importance of the photosyntate mobilization to pods and seeds under intermittent drought stress.

Contributors: J. Polanía, M. Grajales, C. Cajiao, R. García, J. Ricaurte, S. Beebe and I. M. Rao

2.1.1.11 Evaluation of drought resistance and yield of 7 genotypes of *Phaseolus vulgaris* inoculated with and without *Rhizobium etli* strain CIAT 632 under greenhouse conditions

Rationale: Published research from Mexico indicated that the inoculation of common bean genotype, Negro Jamapa, with over expressed trehalose-6-phosphate synthase gene in recombinant strain of *Rhizobium etli* CE3, increased grain production of common bean that was subjected to drought under greenhouse conditions. Before considering bean inoculation with mutant or recombinant strain of *Rhizobium etli* CE3, it is necessary to validate the efficacy of inoculation to improve bean growth under greenhouse conditions. We evaluated the response of 7 common genotypes to inoculation under terminal drought stress or maintenance of 80% of field capacity (well watered) in sterilized soil inoculated with or without *Rhizobium etli* CIAT 632 using greenhouse soil tube method.

Materials and methods: A greenhouse study was conducted at CIAT - Palmira using a mix of an Andisol (from Darien of Colombia) with river sand (2:1 w/w), sterilized with steam for 2 h each day for 2 days and packed in soil cylinders (80 cm of height with 7.5 cm of diameter). Soil was fertilized with nutrients (kg ha^{-1} of 80 N, 50 P, 100 K, 101 Ca, 29.4 Mg, 20 S, 2 Zn, 2 Cu, 0.1 B and 0.1 Mo). The trial included 7 bean genotypes: BAT 477, BAT 477NN, DOR 364, DOR 364NN, Negro Jamapa, Pinto Villa and Alubia Cerrillos. The trial was planted as a randomized complete block arrangement with two levels of water supply: 80% field capacity (well-watered), and withholding of watering (to simulate terminal drought stress conditions); and 3 replications. For the treatment with inoculation, we added 1 ml of inoculum with the strain of *Rhizobium etli* CIAT 632, cultivated in YMA (yeast mannitol agar) liquid. Treatments of terminal drought were imposed at 14 days after planting. Plants with well-watered treatment were maintained by weighing each cylinder every two days and applying water to the soil at the top of the cylinder and plants with terminal drought were monitored for water stress by weighing each cylinder every two days for determination of decrease in soil moisture. Plants were harvested at the age of 35 days after establishment, i.e., 21 days of withholding of water application.

After 2 weeks of establishment a number of shoot physiological characteristics were measured at weekly intervals: total chlorophyll content (SPAD) by chlorophyll meter SPAD-502; chlorophyll fluorescence FV'/FM' by Fluorpen FP-100 (PSI – Photon Systems Instruments); stomatal conductance by porometer SC1 (Decagon Devices) and leaf temperature depression by the infrared thermometer (Telatemp model AG-42D**)**. At the time of harvest, the following plant attributes were measured: leaf area; dry weight of stems, leaves, and pods; and root parameters including nodulation (nodules number and dry weight), root length and biomass distribution at different soil depths (0-5; 5-10; 10-20; 20-40; 40-60; 60-75 cm). Roots in each soil layer were washed free of soil and sand and root length, mean root diameter, specific root length, and root dry weight were measured. Root length and mean root diameter were measured using an image analysis system (WinRHIZO, Regent Instruments INC.).

Results and Discussion: The average of soil moisture at 35 days after planting in the drought treatment was at 50% of field capacity and the maximum temperature in the greenhouse was between 35 to 40^{o}C and the minimum temperature was between 19 to 20^{o}C. Terminal drought condition decreased the nodulation, biomass production, and leaf area of all bean genotypes studied (Table 35). But there was no response to inoculation with the strain *Rhizobium etli* CIAT 632 either in well watered or with terminal drought treatment in terms of shoot biomass and leaf area. The inoculation only increased the nodule number and their dry weight under terminal drought (Table 36). The steam sterilization of soil for 2 h each day for 2 days was not adequate to eliminate native Rhizobia. Alubia Cerillos was found to be more sensitive to drought in terms of shoot biomass and leaf area reduction compared with the well watered condition (Table 35).

Table 35. Effect of inoculation and drought on nodulation, shoot biomass and leaf area.

Genotypes	Nodules number per plant				Nodules dry weight per plant (g)			
	Well watered		Terminal drought		Well watered		Terminal drought	
	+ Inoc	- Inoc	+ Inoc	- Inoc	+ Inoc	- Inoc	+ Inoc	- Inoc
Pinto Villa	111	82	21	16	0.030	0.030	0.003	0.003
Alubia Cerrillos	189	168	37	5	0.088	0.074	0.011	0.007
Negro Jamapa	241	362	45	30	0.116	0.047	0.008	0.003
BAT 477	123	157	8	5	0.035	0.046	0.0008	0.001
BAT 477NN	0	0	0	0	0	0	0	0
DOR 364	138	131	12	2	0.061	0.081	0.003	0.0003
DOR 364NN	0	0	0	0	0	0	0	0

Genotypes	Leaf area (cm^2 $plant^{-1}$)				Shoot biomass (g $plant^{-1}$)			
	Well watered		Terminal drought		Well watered		Terminal drought	
	+ Inoc	- Inoc	+ Inoc	- Inoc	+ Inoc	- Inoc	+ Inoc	- Inoc
Pinto Villa	517.2	551.8	195.5	165.5	5.28	5.10	1.58	1.62
Alubia Cerrillos	724.8	643.0	89.4	120.1	5.90	5.30	0.73	0.68
Negro Jamapa	752.7	836.4	187.0	178.8	4.38	4.50	0.97	1.07
BAT 477	538.0	617.5	79.4	87.5	3.67	3.96	0.90	1.01
BAT 477NN	704.4	589.3	123.7	146.0	6.18	4.06	1.02	1.04
DOR 364	756.9	770.2	192.5	185.0	4.69	5.12	1.09	0.94
DOR 364NN	958.5	757.2	133.9	200.0	7.03	5.74	1.04	1.20

Table 36. Effect of inoculation under terminal drought on nodule number and weight at 35 days after planting.

CIAT 632	Number		Weight (g)	
	Well watered	Terminal drought	Well watered	Terminal drought
+ Inoc	120	17	0.05	0.0037
- Inoc	129	8	0.04	0.0012
LSD $_{0.05}$	28	7	0.023	0.0017

All genotypes decreased the stomatal conductance after two weeks of drought stress but the decrease was more pronounced with Pinto Villa than the other genotypes (Figure 34). This ability to reduce stomatal conductance contributed to its superior performance under drought stress. BAT 477 and its nonnodulating line BAT 477NN maintained their photosynthetic efficiency (yield of quantum efficiency) during drought stress (Figure 34). There were no significant differences between the nodulating and nonnodulating lines because the N supply from soil was adequate.

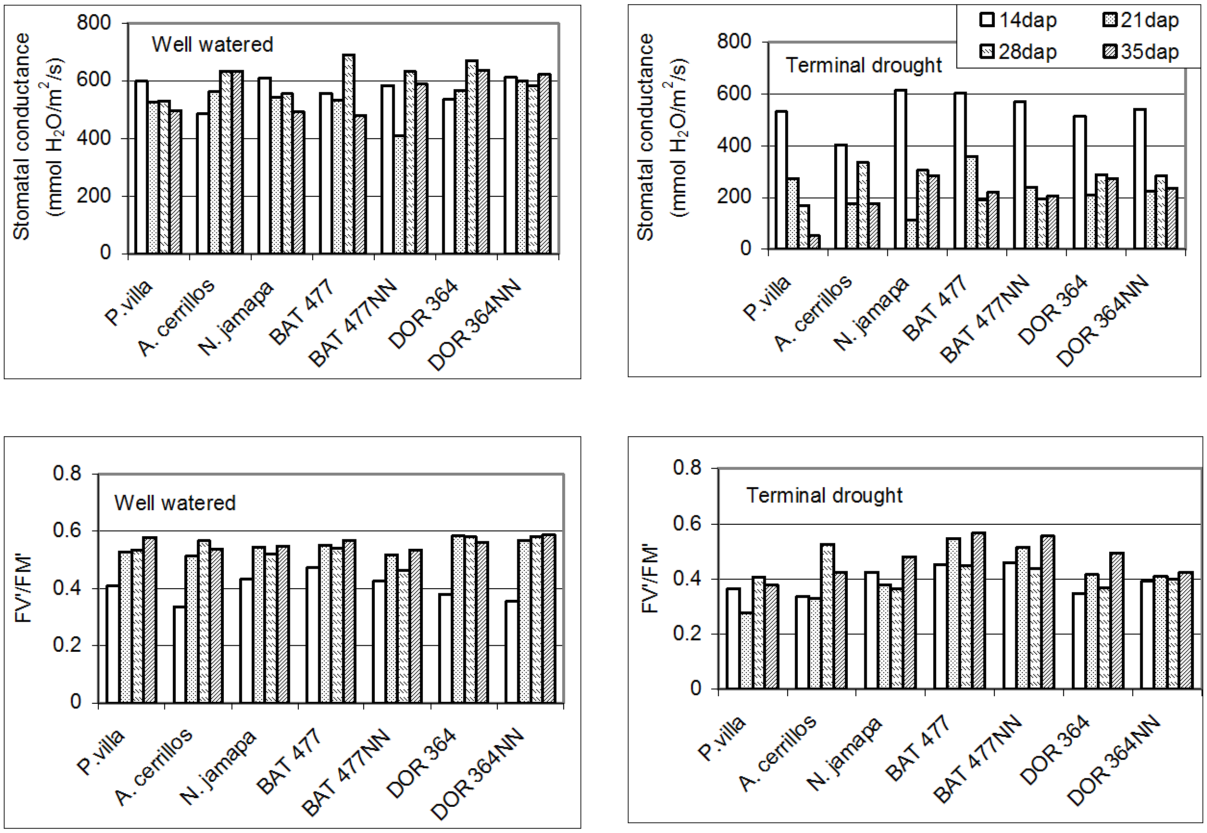

Figure 34. Stomatal conductance and photosynthetic efficiency of 7 genotypes under well watered and drought stress conditions at different days after planting (dap).

Conclusions: The greenhouse soil tube method was found to be very effective in simulating drought stress and the genotype Pinto Villa was better adapted to drought due to its ability to decrease stomatal conductance while Alubia Cerrillos was more affected due to drought stress. Although there was no response to inoculation with the strain *Rhizobium etli* CIAT 632, the effect of terminal drought stress on nodulation was very marked. Soil sterilization with steam was not effective in eliminating native Rhizobia. We need to use a soil type with low nitrogen availability and improve the efficiency of sterilization of soil to test the response to inoculation.

Contributors: N. Asakawa, E. Melo, and I. M. Rao

2.1.2 Aluminum resistance

Highlights:

- Lines derived from an interspecific cross of SER 16, a drought resistant line, by *Phaseolus coccineus* (G35346) yielded well under both rainfed and aluminum toxic conditions. Some actually yielded more in intermittent drought than SER 16.
- SER 16 proved to be an excellent common bean parent to cross with *P. coccineus*, perhaps due to its characteristic of excellent remobilization to grain.
- A filter paper-styrofoam sandwich germination method was developed to improve the phenotyping capacity for Al resistance in common bean and a primary root marking method was developed to evaluate short-term effects of Al on root elongation process.
- A method was adapted and validated for screening for aluminum resistance in common bean based on qualitative determination of aluminum-complexing compounds including citrate released from the roots.
- Phenotypic evaluation of 20 common bean genotypes for aluminium resistance confirmed the higher level of Al resistance of three Andean genotypes (ICA Quimbaya, BRB 198 and G5273) and identified one Mesoamerican genotype (G24601) also with higher level of Al resistance.
- Phenotypic evaluation of 97 RILs of DOR 364 x BAT 477 for aluminium resistance resulted in identification of a few RILs with low inhibition of root growth under high Al in solution. Two RILs (BT 21138-128-1-M-M-M and BT 21138- 2-1-1-M-M-M) were found to be outstanding in root growth both with and without aluminum in solution.

2.1.2.1 Evaluation in two environments, of interspecific lines selected under aluminum toxicity

Rationale: Aluminum toxicity is a primary constraint of crops in tropical soils, limiting root development and nutrient and water capture. *Phaseolus vulgaris* is considered to be relatively sensitive to aluminum, while previous field observations of *Phaseolus coccineus* and subsequent greenhouse evaluations demonstrated that this latter species has superior aluminum tolerance. Aluminum toxicity is thought to exacerbate drought stress by limiting access to soil moisture. Thus, combining resistance to drought and tolerance to aluminum is an important objective. Interspecific crosses were created for this purpose.

Materials and Methods: Two drought resistant common bean parents (Mesoamerican SER 16; Andean ICA Quimbaya) were crossed to several accessions of *P. coccineus* (G35346; G35066; G35464) that had been selected in the field based on vegetative vigor in an aluminum toxic soil. The F_1 plants were backcrossed to the common bean parent, and pedigree selection for vigor was practiced over several generations in the field in an aluminum toxic soil in Santander de Quilichao, from the F_2 to the F_4 generation when selection was performed under drought pressure. These families had reached the F_5 generation at the time of this evaluation, while other selections that were not planted in the drought season and had only been subjected to selection for aluminum tolerance were in the F_4.

Ninety F_4 and F_5 families were planted in Palmira under rainfed conditions in the dry season (July-September, 2008). Two-row plots 3.75 m long were used in three replications. Ten check lines were included to complete a 10 x 10 lattice design. Checks included elite drought selections as well as intraspecific selections for aluminum tolerance from previous breeding work. The same trial was planted in Santander de Quilichao in an aluminum toxic soil (66% saturation) in a lattice design with 4 replications in the October-January planting season. Data on yield and days to maturity were taken, and yield per day was calculated as an indicator of crop efficiency in remobilization of biomass to grain.

Results and Discussion: In the rainfed treatment, the crop received an estimated 170 mm of moisture derived from one irrigation with sprinklers, one furrow irrigation, and 115 mm of rainfall up to 68 days from planting. However, drought stress was only moderate, due to excellent soil structure and cloudy days with low evapotranspiration. Based on common checks in another irrigated trial, yield reduction was estimated to be 25-30%. Under these conditions several lines yielded exceptionally well, and two lines (ALB's 205 and 167) significantly outyielded the drought tolerant parent, SER 16 (Table 37). This yield advantage was in part due to a longer growth cycle, these lines being 5-6 days later to mature than SER 16. Nonetheless, these lines maintained their efficiency, yielding marginally better per day than SER 16. Other elite lines from previous years (e.g., BAT 477; A774; Tio Canela) presented comparable days to maturity as the ALB lines but yielded less. Thus it appears that better yield potential with the ability to resist at least moderate drought stress has been obtained in some lines. This may reflect improved rooting derived from G35346 combined with good remobilization of biomass to grain, derived from SER 16.

Table 37. Best yielding lines and checks of interspecific progeny under intermittent drought, Palmira, and aluminum toxicity, Santander de Quilichao, Colombia. 2008.

				Rainfed					Aluminum toxicity				
Tr	Parents / identification	Line	COL.	Rsnk	DTF	DTM	kg ha^{-1}	kg ha^{-1} d^{-1}	Rsnk	DTF	DTM	kg ha^{-1}	kg ha^{-1} d^{-1}
83	SER 16 X (SER 16 x G35346-3Q)	ALB 205	rd	1	35	68	3199	46,9	46	35	63	656	10.4
61	SER 16 X (SER 16 x G35346-3Q)	ALB 167	rd	2	37	69	3174	45,7	27	35	64	716	11.2
90	SER 16 X (SER 16 x G35346-3Q)	ALB 213	rd	3	33	67	3029	45,3	19	34	61	755	12.5
54	SER 16 X (SER 16 x G35066-1Q)	ALB 159	br, cr	4	33	68	2974	43,4	60	35	63	591	9.5
15	SER 16 X (SER 16 x G35346-3Q)	ALB 188	rd	5	33	67	2891	43,1	13	37	66	779	11.9
67	SER 16 X (SER 16 x G35346-3Q)	ALB 180	rd	6	32	64	2887	45,0	63	34	61	582	9.6
62	SER 16 X (SER 16 x G35346-3Q)	ALB 168	rd	7	33	68	2883	42,4	37	34	62	684	11.4
20	SER 16 X (SER 16 x G35346-3Q)	ALB 214	rd	8	35	71	2879	40,4	9	36	64	846	13.3
100	((VAX 1 x BRB191) x G21212) x (RAB 655 x G22041)	ALB 252		9	38	70	2824	40,3	5	38	64	882	13.7
31	SER 16 X (SER 16 x G35346-3Q)	ALB 204	rd	10	36	68	2781	40,8	1	34	63	906	14.4
60	SER 16 X (SER 16 x G35346-3Q)	ALB 166	rd	11	37	69	2761	40,1	93	37	63	399	6.4
21	SER 16 X (SER 16 x G35346-3Q)	ALB 215	rd	12	34	65	2722	41,7	7	33	59	859	14.5
76	SER 16 X (SER 16 x G35346-3Q)	ALB 197	rd	13	33	65	2720	41,9	39	34	60	681	11.4
87	SER 16 X (SER 16 x G35346-3Q)	ALB 210	rd	14	38	68	2714	39,4	79	39	63	525	8.3
17	SER 16 X (SER 16 x G35346-3Q)	ALB 190	rd	15	34	71	2695	38,1	21	36	63	749	11.9
96	G 21212		bl	16	38	68	2682	39,1	4	35	63	883	13.8
22	SER 16 X (SER 16 x G35346-3Q)	ALB 216	rd	17	38	71	2674	37,3	55	38	65	610	9.3
94	VAX 1		Cr str	18	38	68	2653	38,9	71	39	65	560	8.7
19	SER 16 X (SER 16 x G35346-3Q)	ALB 208	rd	19	33	66	2625	39,8	19	33	62	877	14.2
48	SER 16 X (SER 16 x G35066-1Q)	ALB 149	rd	20	33	66	2620	39,4	54	33	62	611	9.8
66	SER 16 X (SER 16 x G35346-3Q)	ALB 179	rd	21	33	64	2614	40,5	25	33	59	720	12.1
85	SER 16 X (SER 16 x G35346-3Q)	ALB 207	rd	22	36	70	2594	36,8	36	36	64	684	10.8
89	SER 16 X (SER 16 x G35346-3Q)	ALB 212	rd	23	33	67	2592	38,9	11	34	61	826	13.4
92	TIO CANELA 75		rd	24	38	68	2581	38,0	31	38	64	704	10.9
65	SER 16 X (SER 16 x G35346-3Q)	ALB 178	rd	25	32	64	2572	40,5	17	33	59	758	12.6
33	ICA QUIMBAYA X (ICA QUIMBAYA x G35464-5Q)	ALB 130	pk	26	32	64	2569	40,1	89	33	61	471	7.9
74	SER 16 X (SER 16 x G35346-3Q)	ALB 195	rd	27	33	67	2568	38,2	14	34	62	773	12.4
99	((G24601 x (MAM 38 x BRB 198)) x G11015) X (MAM 38 x G21212)	ALB 229	Cr br	28	38	71	2567	35,7	28	39	67	715	10.6
88	SER 16 X (SER 16 x G35346-3Q)	ALB 211	rd	29	33	65	2563	39,5	3	33	60	896	14.9
16	SER 16 X (SER 16 x G35346-3Q)	ALB 189	rd	30	32	65	2554	39,1	34	34	64	698	10.9
98	((VAX 1 x BRB 191) x G21212) x (RAB 655 x G22041)	ALB 253	v	31	38	70	2550	36,3	40	39	66	676	10.3
63	SER 16 X (SER 16 x G35346-3Q)	ALB 169	rd	32	34	67	2528	37,6	82	35	63	514	8.2
91	SER 16		rd	33	32	63	2520	40,3	23	32	58	742	12.7
97	A 774		Cr	34	36	68	2517	37,3	26	37	63	719	11.3
93	ICA QUIMBAYA		rd	38	33	68	2453	36,1	99	32	65	294	4.5
95	BAT 477		Cr	68	38	68	2165	31,8	24	40	63	733	11.5
	LSD (0.05)				**1.8**	**2.4**	**568**	**8.1**		**1.8**	**2.0**	**231**	**3.7**

COL=color; bl=black; rd=red; cr str=cream striped; pk=pink; v=variable; DTF=Days to flower; DTM=Days to maturity.

In the aluminum toxicity treatment, no line significantly outyielded the SER 16 recurrent parent, which in fact resulted to be intermediate in its reaction to aluminum. Thus, based on this data it cannot be stated that we successfully transferred improved aluminum tolerance from *P. coccineus* to SER 16. However, several lines outyielded the tolerant check, VAX 1, by as much as 60%. What was more important is that a few lines performed relatively well in both treatments (Table 37). In the rainfed and aluminum treatments, respectively, ALB 213 ranked 3rd and 19th, ALB 188 ranked 5th and 13th, ALB 214 was 8th and 9th, ALB 252 was 9th and 5th, and ALB 204 was 10th and 1st. The correlation in yield across the two treatments was 0.54. These lines merit wider evaluation, given their positive performance and the fact they represent unusual genetic variability that has not previously been exploited in cultivated common bean. We speculate that it was possible to obtain better progenies from this cross as compared to other interspecific crosses in the past, due to SER 16's excellent remobilization of biomass to grain. We hypothesize that that this trait serves to overcome the tendency for such crosses to produce lines with excessive vegetative growth and poor harvest index.

Collaborators: S. Beebe, I. Rao, C. Cajiao, M. Grajales, M.L. Cortés, A.F. Guerrero

2.1.2.2 Improving phenotyping capacity to evaluate for aluminum resistance

Rationale: Screening for Al resistance using hydroponic-based methodology normally requires that large amounts of genotypes or accessions should be tested at the same time under the same climatic and experimental conditions. Independently of the amount of materials to be tested, obtaining healthy and homogenous plantlets or seedlings to reduce the variability originating in the germination process is of great importance. Previously, germination of bean seedlings involved use of growing mediums such as peat, sand or a mix of both substrates. However, this method is time consuming, special skills are required to clean the peat from the roots in order to reduce the interference with the Al in the nutrient solution and in many cases the roots are not uniform. Normally, it was required up to 16 h to establish, germinate and transplant a trial with 60 genotypes. In spite of careful manipulation, in the end high standard deviations did not allow clear differentiation between genotypes for their level of Al resistance.

Materials and Methods: After reviewing the previous method used in the screening of bean for Al resistance, some key modifications were made to increase the capacity to screen larger number of genotypes while reducing the time needed for the establishment and the sources of variability between replicates. These key modifications in order of importance were:

1. Replacing the sand-based germination by filter-paper/styrofoam sandwiches;
2. Manipulation of plantlets during the transplant to nutrient solution to avoid damage of basal roots (very important in the determination of root architecture parameters);
3. Measuring root length after 24 or 48 h of Al treatment using marked roots (important to correlate with physiological studies);
4. Controlling the pH of the nutrient solution, especially during the preparation of the Al treatments;
5. Controlling the aeration system to avoid root damage during the treatment time.

Results: After the implementation of the sandwich system to germinate the plants, healthy (straight tap and basal roots) and homogenous plantlets were obtained (Figure 35 b and c), allowing quick selection of pairs of seedlings to be transplanted to containers with or without Al. The time to arrange and establish the whole germination system is less than 2 h, and after germination the transplanting of 120 genotypes (15 seeds x 2 treatments x 4 replicates) corresponding to circa 14,400 seeds could be completed in less than 4 h.

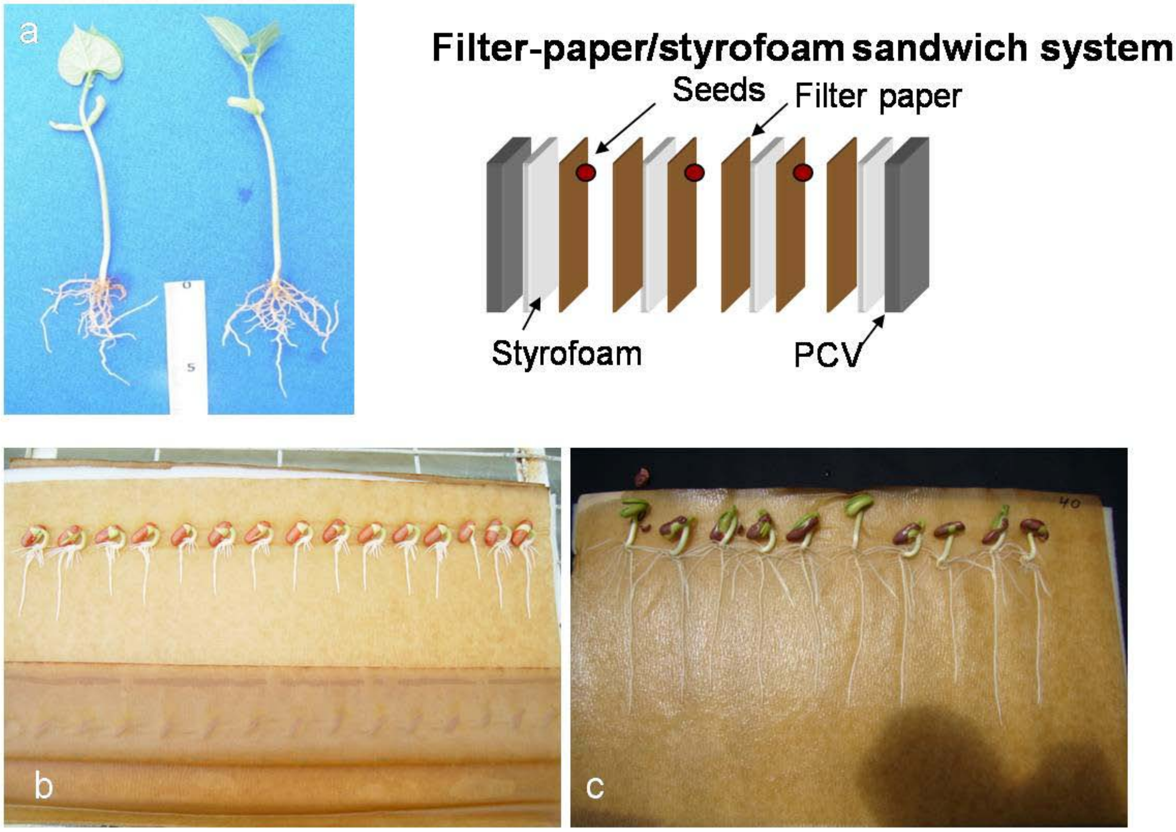

Figure 35. Comparison between seedlings germinated in sand (a) or in filter-paper/Styrofoam sandwich system after 3 (b) or 4 days (c) of germination.

Physiological studies of Al resistance normally require measurements of root elongation of tap and basal roots during short periods of time (few hours) after Al treatment. Marking roots (Figure 36) 3 cm above the root tip (root zone already differentiated) just prior to the Al treatment, allows measuring the direct effect of Al on root elongation at different Al treatment times. After obtaining homogenous seedlings from the germination system, results from Figure 37 shows that no noticeable differences were observed between marked and complete root measurement methods using an Al resistant Quimbaya and Al sensitive VAX 1 genotypes. Therefore, for routine screening of Al resistance the complete root measurement could be used. However, to measure the Al effect during short or consecutive treatment times, the marking method is recommended.

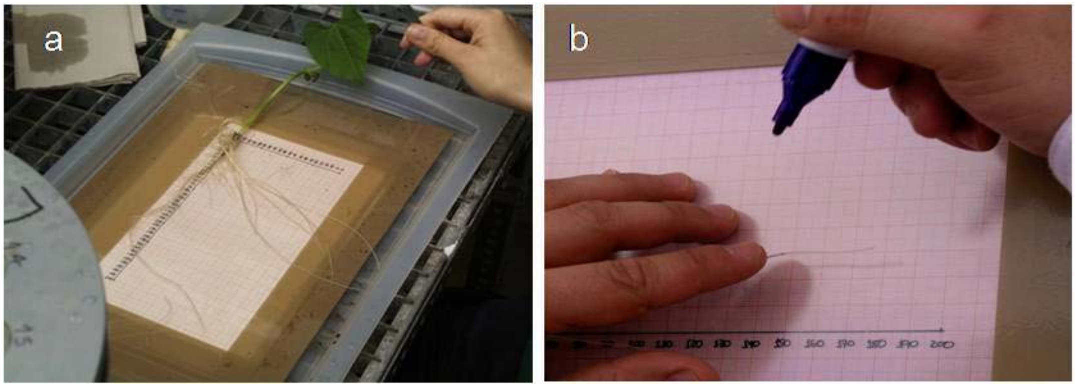

Figure 36. Root elongation measured with two methods: a) complete root and b) marking 3 cm above the root tip.

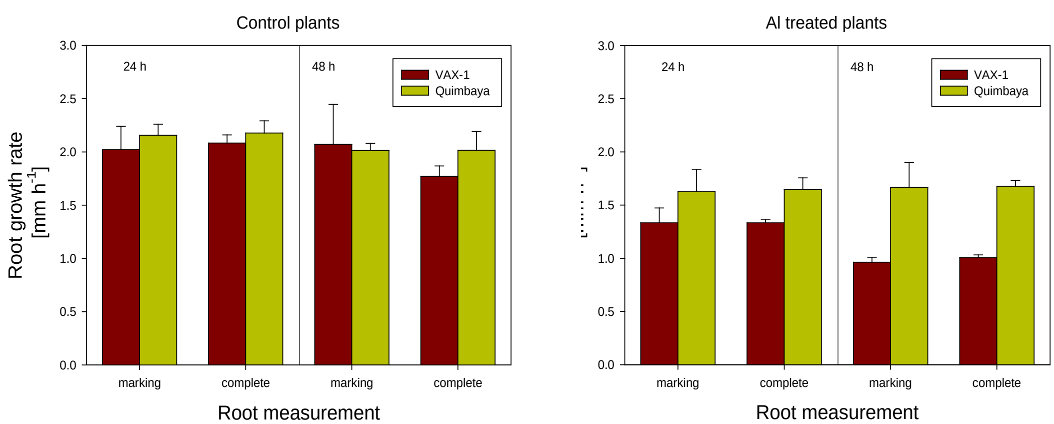

Figure 37. Influence of two different methods (marking and complete root) to measure root growth rates of two common bean genotypes (Al-resistant, Quimbaya; Al-sensitive VAX-1) after germination using filter-paper/styrofoam germination system.

Conclusions: A filter paper-styrofoam sandwich germination method was developed to improve the phenotyping capacity for Al resistance in common bean and a primary root marking method was developed to evaluate short-term effects of Al on root elongation process.

Contributors: A.F. Rangel, J. Ricaurte, S. Beebe, I. M. Rao (CIAT); W. Horst (Leibniz University of Hannover, Germany)

2.1.2.3 Qualitative indication of Al-induced citrate exudation in different *Phaseolus* species using an Agarose-Aluminon method

Rationale: Previous studies have shown that citrate exudation contributes to Al resistance in common bean. Two protocols were implemented in order to check the contribution of citrate exudation to Al resistance in different *Phaseolus* species using 1 cm excised root tips in nutrient solution (quantitative) or intact plants in agarose gels containing aluminon as color indicator (qualitative). The agarose gel technique shows that organic acid exudation occurs along the entire root system but mainly to the first 1 to 2 cm of the root tip, the most Al sensitive root zone. The amount of organic acids secreted to the agarose media of the three Phaseolus species tested decreased in the order of *P. coccineus* > *P. vulgaris* > *P. acutifolius*. The presence of Al-complexing chelators in root exudates and rhizosphere soil solution can be visualized using agarose gels, containing red-colored Al-aluminon complexes on the root surface. The presence of Al chelators with higher affinity to Al, compared to aluminon (e.g. organic acid anions, phenols) is indicated by discoloration zones.

Materials and methods: Gels of agarose (low gelling point) of 3 mm (1 % w/v) were used as carrier matrix for the Al-aluminon complex. Agarose gels were prepared in nutrient solution containing 5 mM $CaCl_2$, 0.5 mM KCl and 8 µM H_3BO_3. Aluminum (250 µM) was added to the agarose containing nutrient solution after cooling down to 50^{o}C and adjusting the pH to 4.5. Aluminon stock solution was prepared by mixing NaOH (24g), Aluminon (175 mg) dissolved in acetic acid (120 ml) and adjusted to 500 ml with bi-distilled water and adjusting the pH to 4.2.

Different bean accessions with contrasting levels of Al-resistance were pretreated for 24 h in nutrient solution containing 20 µM of Al. This treatment time is enough to detect significant differences in Al resistance among common bean genotypes based on inhibition of root elongation. Also, it has been demonstrated that these differences corresponded with the capacity to exude organic acid anions, mainly citrate. After Al pretreatment four plants of each accession were carefully placed into flat transparent acrylic cuvettes, the root system was dispersed and a mix of 25 ml aluminon, 70 ml of agarose containing nutrient solution and Al, and 5 ml ascorbic acid (0.5%) at 40^{o}C, was carefully poured to cover the whole root system (3 to 4 mm thickness). Thereafter, the cuvettes were covered with plastic sheet to avoid desiccation of the agarose. Depending on the amount of Al-complexing compounds released from the root or accumulated in the rhizosphere, discoloration was visible after 6 to 8 h.

Results: In general terms, the appearance of bleached zones were observed in the complete root system but mainly in the first 1 to 2 cm root apices. Similarly, all accessions showed the capacity to exude Al-chelating substances from the roots. However, the grade and magnitude of discolored areas were in the order of *P. acutifolius* < *P. vulgaris* < *P. coccineus*. Additionally, the extent of discolored areas were in agreement with the known Al resistance rating of all six accessions used, so less blanched areas were observed in G40159 and VAX-1, both rated as Al-sensitive. SER16, an Al-intermediate accession, showed discolored areas mainly in the first 1 to 2 cm from the root tips and in areas where more root tips appeared. G19833, Quimbaya and G35346-3Q, all classified as Al-resistant, showed a greater capacity to exude Al-chelating substances along the whole root system (Figure 38). However, the capacity to exude these substances by the coccineus accession was outstanding. The validation of this result requires quantification of the Al-chelating substances exuded from the roots. According to previous studies, this should correspond mainly to citrate exudation. Thus, this method can be used as a fast test to check the existence of citrate exudation as a mechanism of Al resistance in different bean accessions.

Conclusions: A method was adapted and validated for screening for aluminum resistance in common bean based on qualitative determination of aluminum-complexing compounds including citrate released from the roots.

Contributors: A.F. Rangel, J. Ricaurte, S. Beebe, I. M. Rao (CIAT); W. Horst (Leibniz University of Hannover, Germany)

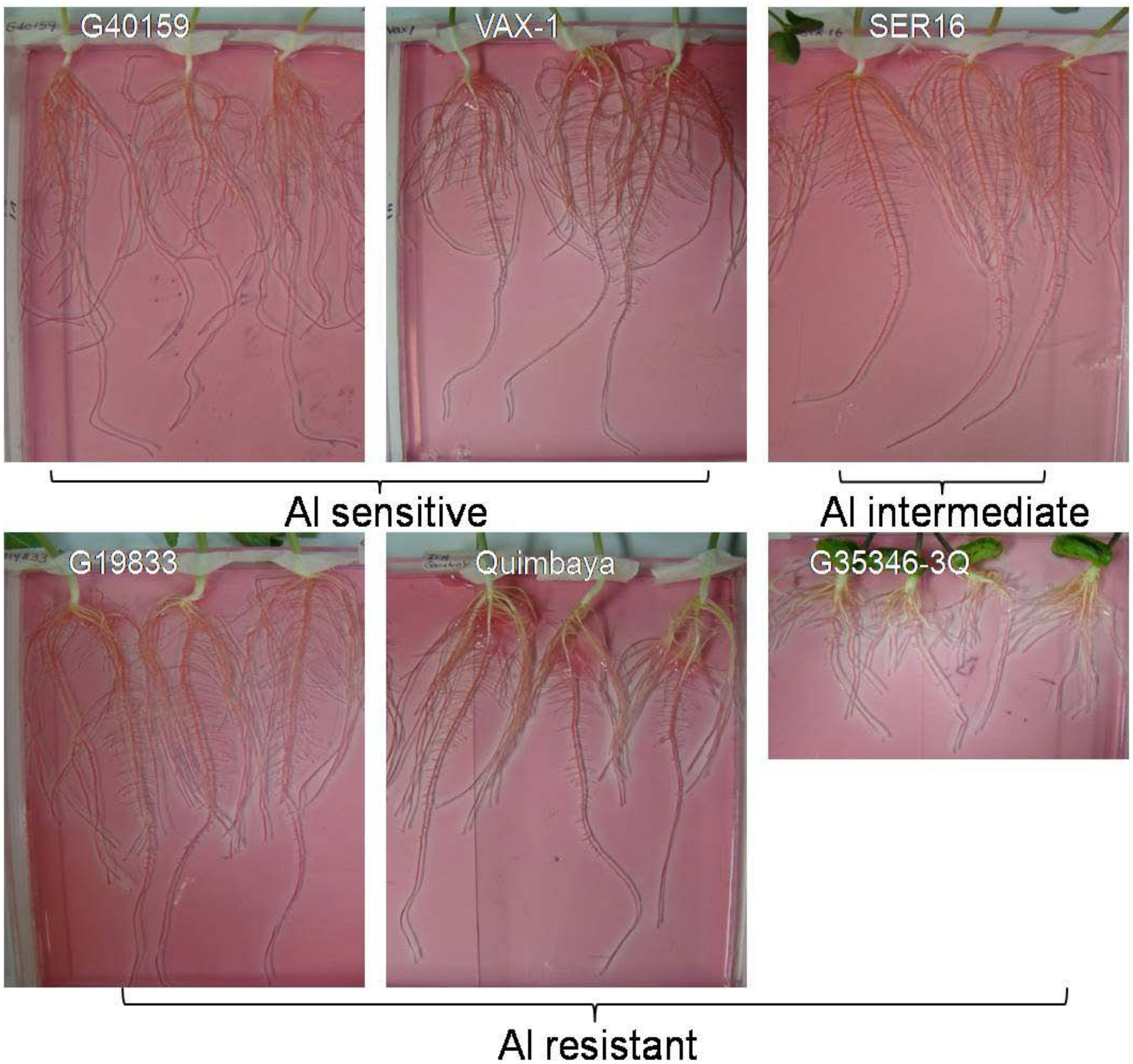

Figure 38. Qualitative determination of Al-complexing compounds (e.g. citrate) released from the roots of six bean genotypes differing in Al-resistance. G40159 (*P. acutifolius*); VAX-1, SER16, G19833 and Quimbaya (*P. vulgaris*); and G35346-3Q (*P. coccineus*).

2.1.2.4 Phenotypic differences in aluminum resistance of landraces and bred lines

Rationale: Toxicity of Al in acid soils in the tropics is a major problem to resource-poor farmers for producing beans. Amending soils with lime is not economically feasible for most farmers. Improving the level of Al resistance in common bean could help farmers to produce beans locally in acid soils with high aluminum. Field screening of 5000 germplasm accessions and breeding lines in Al-toxic soils with and without lime (65% Al saturation) indicated significant genotypic variation in seed yield. Likewise, significant genotypic differences for Al resistance have been found in nutrient-solution based screenings using inhibition of root elongation after 48 h at 20 µM Al supply as a parameter for Al injury. The present work aimed to identify bean genotypes with Al resistance as determined by Al-induced inhibition of principal root elongation and total root length per plant. Genotypic differences in root vigor in the absence of Al in nutrient solution were also evaluated to identify genotypes that combine Al resistance with high root vigor.

Materials and Methods: Three days old seedlings of 20 common bean genotypes listed in Table 38 were grown in nutrient solution containing 5 mM $CaCl_2.2H_2O$, 0.5 mM KCl and 8 µM H_3BO_3 under glasshouse environmental conditions at CIAT-Palmira. After 2 days of pH adjustment from 5.5 to 4.5 with a step wise decrease, plants were exposed to either 0 or 20 µM $AlCl3.6H_2O$ for up to 2 days (Figure 39). The experiment was repeated twice with 4 replications and the mean values are reported. Primary root elongation rate (mm h^{-1}) was measured through marking of the primary root 3 cm above the root tip at the beginning and at the end of the treatments. The difference between the two markings was used to measure primary root elongation rate and percent inhibition of root elongation rate due to Al treatment. At 48 h of treatment with or without Al, total root length (cm $plant^{-1}$), mean root diameter (mm), root volume (cm^3 $plant^{-1}$) and surface root area (cm² $plant^{-1}$) were measured using Winrhizo software (WinRHIZO 2003, Regent Instruments INC). Root weight (g $plant^{-1}$) was determined after drying roots until constant weight in an oven at 60 ^oC for 48 h. Specific root length (m g^{-1}) was calculated dividing root length by root weight.

Results: Root growth of all genotypes (Al-resistant and Al-sensitive) was inhibited by Al treatment (Figures 40 and 41). Three Andean bred lines (ICA Quimbaya, BRB 198 and G5273) and one Mesoamerican accession (G24601) showed resistance to Al in solution. Three Mesoamerican bred lines (VAX 1, ALB 220, BAT 477) were found to be more sensitive to Al in solution. Two bred lines (ALB 230, ALB 218) that combined Mesoamerican, Jalisco and Andean races showed higher values of root growth both without and with Al stress (Table 38). BAT 477 showed greater root vigor in the absence of Al in solution. Among the six INB lines tested, INB 606 showed intermediate level of Al resistance (Figures 40 and 41).

Conclusions: Phenotypic evaluation of 20 common bean genotypes for aluminum resistance resulted in identification of three Andean genotypes (ICA Quimbaya, BRB 198 and G5273) and one Mesoamerican genotype (G24601) with higher level of Al resistance.

Contributors: J. Ricaurte, R. García, A. F. Rangel, S. Beebe, I. M. Rao (CIAT); W. Horst (Leibniz University of Hannover, Germany)

Table 38. Description of 20 common bean genotypes (ordered by inhibition of primary root elongation, Figure 40) grown in a solution containing 0.5 mM Ca, 0.5 mM K and 8 µM B with or without 20 µM Al for 48 h, pH 4.5.

Genotype	Origin	Race	Species	Pedigree
ICA Quimbaya	CIAT	N		Canadian Wonder x A 487 G 6592 x A 487
BRB 198	CIAT	N		CAL 192 x MCR 2515
G 5273	MEXICO	N		CIAS 72
INB 606	CIAT	M	*P. vulgaris* x *P. acutifolius*	BKI 11 X DOR 390/-1C-1C-1C-1C-MC-MC-MC
ICA Pijao	COLOMBIA	M		ICA Pijao G 5773
G 19833	PERU	N		Chaucha Chuga
RAB 655	CIAT	M		(VAX 3xMAM 38)-1/-(NN)Q-115Q-(NN)Q-(NN)Q-(NN)C-(NN)C-(NN)Q
INB 108	CIAT	M	*P. vulgaris* x *P. acutifolius*	ICA Pijao x G40001
MAM 38	CIAT	J		A 409 x (BAT1670 x G4000 x XAN112)
ALB 218	CIAT	**M** x J xN = M		G 24601 x (G 22041 x BRB 198)F2/-MQ-7Q-2Q-MQ-MQ-7Q-MC
INB 604	CIAT	M	*P.vulgaris* x *P.acutifolius*	DCBC-V x DCBC-V/-F5-MC-14C-MC-MC-MC
ALB 230	CIAT	**M x** J x N = M		((G 24601x(MAM 38xBRB 198)F1)F1x**G 11015**)F1 X (MAM 38x**G 21212**)F1/-MQ-15Q-MQ-MQ-12Q-MC
G40001	MEXICO	*P.acutifolius*	*P. acutifolius*	
INB 605	CIAT	M	*P. vulgaris* x *P. acutifolius*	DCBC-V x DCBC-V/-F5-MC-4C-MC-MC-MC
INB 603	CIAT	M	*P. vulgaris* x *P. acutifolius*	DCBC-V x DCBC-V/-F5-MC-4C-MC-MC-MC
INB 109	CIAT	M	*P. vulgaris* x *P. acutifolius*	ICA Pijao x G40001
BAT 477	CIAT	M		(51051 x ICA Bunsi)F1 x (51052 x Cornell 49-242)F1/-CM(11-C)-M-CM(8-C) (G 3834 x G 4493)F1 x (G 4792 x G 5694)F1/-CM(11-C)-M-CM(8-C)
ALB 220	CIAT	M		RAB 655 X (MAM 49 X RIB 66)F1/-MQ-MQ-MQ-8Q-MQ-MQ-14Q-MC
VAX 1	CIAT	M		A 769 x(A 775 x (G 5773 x G40001-B1)

Race: M = Mesoamerica; J = Jalisco; N = Nueva Granada
Pedigree: Local names at country of origen; CIAT codes

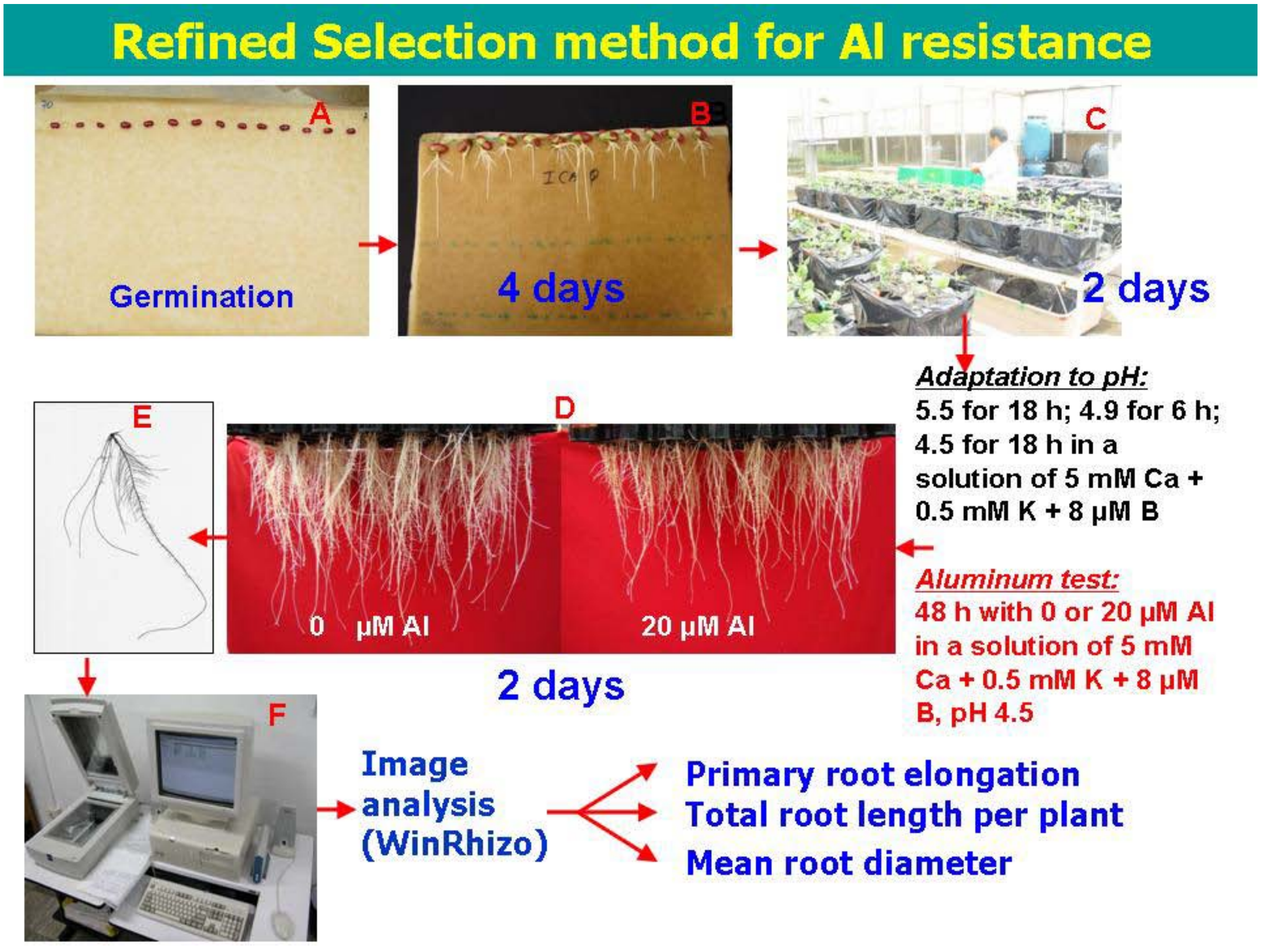

Figure 39. Refined methodology to evaluate aluminum resistance in common bean genotypes using nutrient solution under greenhouse conditions. A and B) seedlings germinated using filter paper-styrofoam sandwich germination paper; C) adapted to pH changes from 5.5 to 4.5; D) aluminum test ; E and F) acquisition and analysis of root images.

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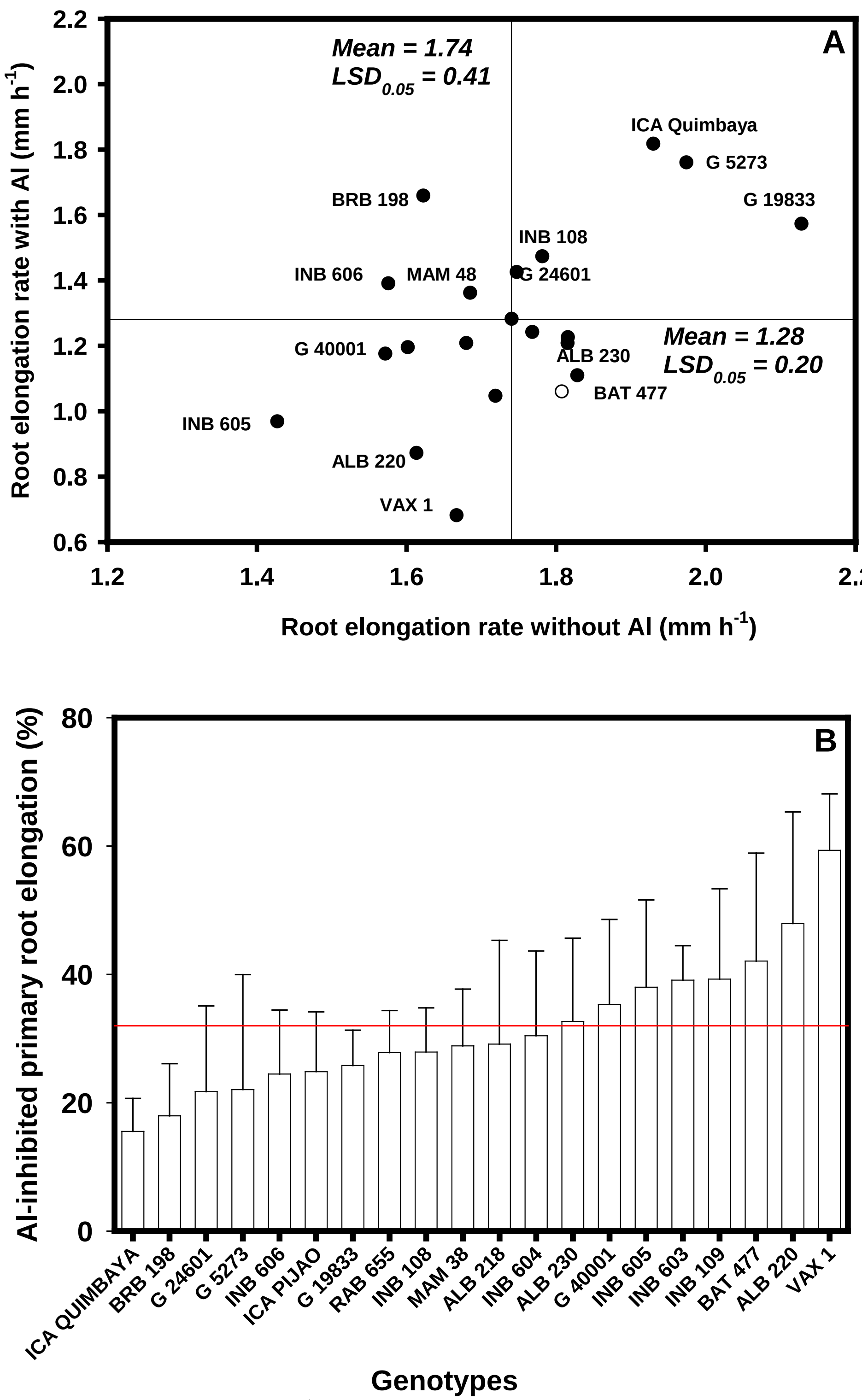

Figure 40. Root elongation rate (A, mm h^{-1}) and inhibition of principal root elongation (B, %) of 20 common bean genotypes grown in a solution containing 0.5 mM Ca, 0.5 mM K and 8 µM B with or without 20 µM Al for up to 48 h, pH 4.5. Bars are means ± SD of eight replicates from 2 experiments. Horizontal line represents the genotypic mean value.

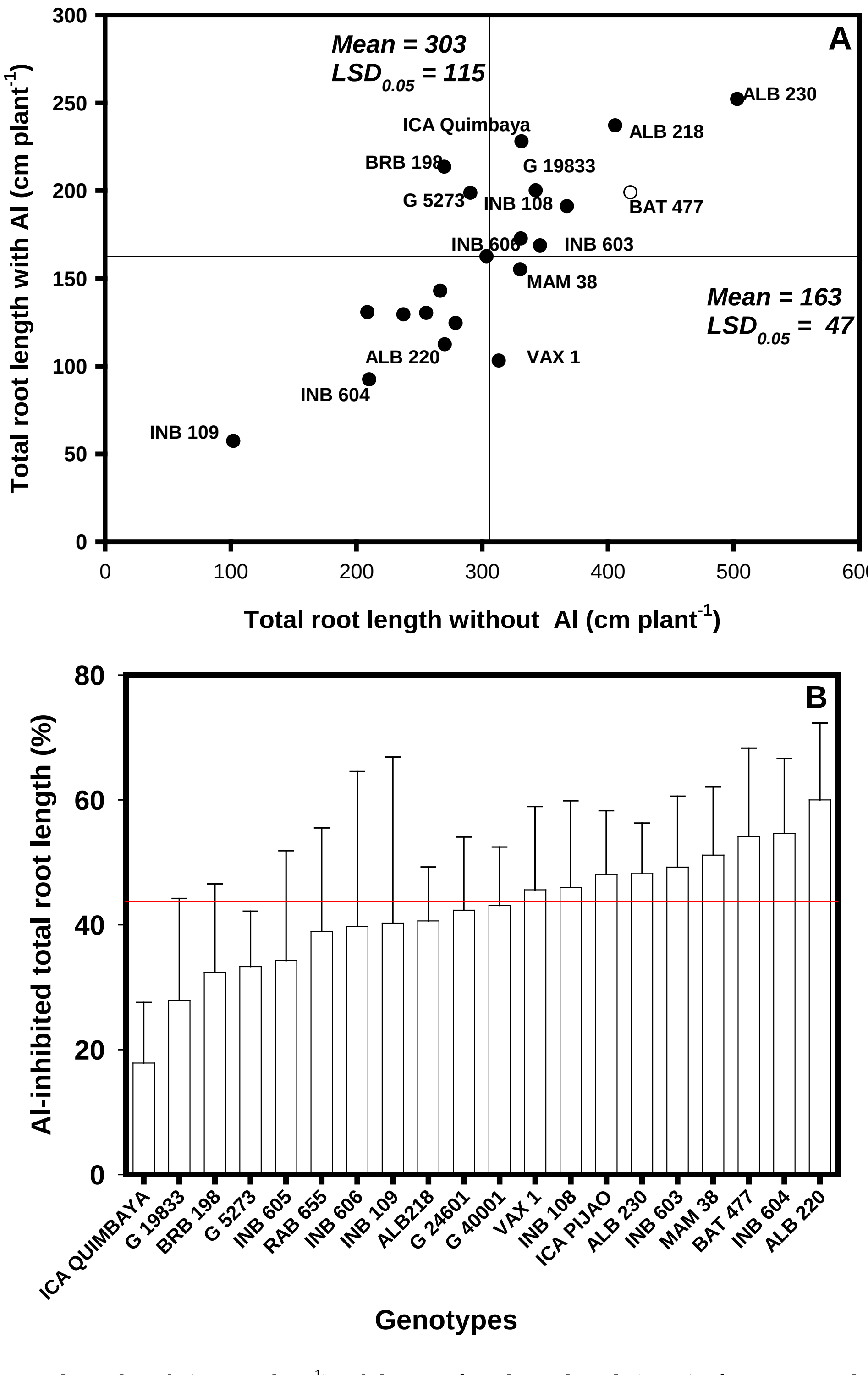

Figure 41. Total root length (A, cm plant^{-1}), inhibition of total root length (B, %) of 20 common bean genotypes grown in a solution containing 0.5 mM Ca, 0.5 mM K and 8 µM B with or without 20 µM Al for up to 48 h, pH 4.5. Bars are means ± SD of eight replicates from 2 experiments. Horizontal line represents the genotypic mean value.

2.1.2.5 Phenotyping for aluminum resistance in recombinant inbred lines (RILs) of DOR364 x BAT 477

Rationale: The present work is aimed to determine differences in resistance to Al-induced inhibition of principal root elongation and total root length of 97 RILs of the cross DOR364 x BAT477. In addition, root vigor without Al in solution is also determined. These phenotypic data will be used to identify QTLs involved in Al resistance in common bean.

Materials and Methods: Three day old seedlings of 100 common bean genotypes (97 RILs of the cross DOR364 x BAT477, two parents and one check, SEA 5; Table 39) were evaluated in nutrient solutions under greenhouse conditions at CIAT Palmira. Seedlings were obtained with germination in 1-2 mm diameter of cleaned sand. Nutrient solutions contained 5 mM $CaCl_2.6H_2O$, 0.5 mM KCl and 8 µM H_3BO_3. After 2 days of pH adjustment from 5.5 to 4.5 with a step wise decrease, plants were exposed to either 0 or 20 µM $AlCl3.6H_2O$ for up to 2 days. The experiment was repeated three times with 3 replications at each time and the mean values are reported. Primary root elongation rate (mm h^{-1}) was measured through marking of the primary root 3 cm above the root tip at the beginning and at the end of the treatments. The difference between the two markings was used to measure primary root elongation rate and percent inhibition of root elongation rate due to Al treatment. At 48 h of treatment with or without Al, total root length (cm $plant^{-1}$), mean root diameter (mm), root volume (cm^3 $plant^{-1}$) and surface root area (cm² $plant^{-1}$) were measured using Winrhizo software (WinRHIZO 2003, Regent Instruments INC). Root weight (g $plant^{-1}$) was determined after drying roots until constant weight in an oven at 60 ^oC for 48 h. Specific root length (m g^{-1}) was calculated dividing root length by root weight.

Results: Root growth of all genotypes (RILs, parents, check) was inhibited by Al treatment (Figures 42 and 43). Al treatment inhibited primary root elongation of DOR 364 and BAT 477 by 57% and 64%, respectively. The 6 outstanding RILs with lower percent inhibition of primary root elongation showed values from 29 (R100=BT 21138_128-1--M-M-M) to 36% (R71=BT 21138_71-1-1-M-M-M). In ascending order they were: R100 (BT 21138_128-1--M-M-M), R39 (BT 21138_39-1-1-M-M-M), R70 (BT 21138_70-1-1-M-M-M), R8 (BT 21138_ 8-1-1-M-M-M), R44 (BT 21138_124-1-1-M-M-M-M-M) and R71 (BT 21138_71-1-1-M-M-M). Total root length inhibition in DOR 364 and BAT 477 was 48% and 36%, respectively. The RILs R84 (BT 21138_84-1-1-M-M-M) , R72 (BT 21138_72-1-1-M-M-M), R61 (BT 21138_61-1-1-M-M-M), R56 (BT 21138_56-1-1-M-M-M), R73 (BT 21138_73-1-1-M-M-M), R41 (BT 21138_41-1-1-M-M-M) and R30 (BT 21138_30-1-1-M-M-M) showed lower values of total root length inhibition (5.0, 23.8, 23.9, 24.2, 24.3, 24.8 and 26.4 respectively). Two RILs (R100 = BT 21138_128-1--M-M-M and R2 = BT 21138_ 2-1-1-M-M-M) were found to be outstanding in root production both with and without Al in solution (Figure 44).

Table 39. Pedigree of 98 RILs of DOR364 x BAT 477 evaluated in a solution containing 0.5 mM Ca, 0.5 mM K and 8 μM B with 0 and 20 μM Al for up to 48 h, pH 4.5.

RIL	Pedigree	RIL	Pedigree	RIL	Pedigree
1	BT 21138_ 1-1-1-M-M-M	**35**	BT 21138_35-1-1-M-M-M	**68**	BT 21138_68-1-1-M-M-M
2	BT 21138_ 2-1-1-M-M-M	**36**	BT 21138_36-1-1-M-M-M	**69**	BT 21138_69-1-1-M-M-M
3	BT 21138_ 3-1-1-M-M-M	**37**	BT 21138_104-3-M-M-M-M-M	**70**	BT 21138_70-1-1-M-M-M
4	BT 21138_ 4-1-1-M-M-M	**38**	BT 21138_38-1-1-M-M-M	**71**	BT 21138_71-1-1-M-M-M
5	DOR 364	**39**	BT 21138_39-1-1-M-M-M	**72**	BT 21138_72-1-1-M-M-M
6	BT 21138_ 6-1-1-M-M-M	**40**	BT 21138_115-1-1-M-M-M-M-M	**73**	BT 21138_73-1-1-M-M-M
7	BT 21138_ 7-1-1-M-M-M	**41**	BT 21138_41-1-1-M-M-M	**74**	BT 21138_74-1-1-M-M-M
8	BT 21138_ 8-1-1-M-M-M	**42**	BT 21138_42-1-1-M-M-M	**75**	BT 21138_75-1-1-M-M-M
9	BT 21138_ 9-1-1-M-M-M	**43**	BT 21138_43-1-1-M-M-M	**76**	BT 21138_76-1-1-M-M-M
10	BT 21138_10-1-1-M-M-M	**44**	BT 21138_124-1-1-M-M-M-M-M	**77**	BT 21138_77-1-1-M-M-M
11	BAT 477	**45**	BT 21138_45-1-1-M-M-M	**78**	BT 21138_131-1-1-M-M-M-M-M
12	BT 21138_12-1-1-M-M-M	**46**	BT 21138_46-1-1-M-M-M	**79**	BT 21138_79-1-1-M-M-M
13	BT 21138_13-1-1-M-M-M	**47**	BT 21138_47-1-1-M-M-M	**80**	BT 21138_80-1-1-M-M-M
14	BT 21138_14-1-1-M-M-M	**48**	BT 21138_48-1-1-M-M-M	**81**	BT 21138_81-1-1-M-M-M
15	BT 21138_15-1-1-M-M-M	**49**	BT 21138_124-1-2-M-M-M-M	**82**	BT 21138_82-1-1-M-M-M
16	BT 21138_16-1-1-M-M-M	**50**	BT 21138_50-1-1-M-M-M	**83**	BT 21138_83-1-1-M-M-M
17	BT 21138_17-1-1-M-M-M	**51**	BT 21138_51-1-1-M-M-M	**84**	BT 21138_84-1-1-M-M-M
18	BT 21138_ 23-1-4-M-M-M-M	**52**	BT 21138_124-1-3-M-M-M-M	**85**	BT 21138_85-1-1-M-M-M
19	BT 21138_19-1-1-M-M-M	**53**	BT 21138_53-1-1-M-M-M	**86**	BT 21138_35-1-4-M-M-M
20	BT 21138_20-1-1-M-M-M	**54**	BT 21138_54-1-1-M-M-M	**87**	BT 21138_147-3-M-M-M-M-M
21	BT 21138_21-1-1-M-M-M	**55**	BT 21138_55-1-1-M-M-M	**88**	BT 21138_88-1-1-M-M-M
22	BT 21138_22-1-1-M-M-M	**56**	BT 21138_56-1-1-M-M-M	**89**	BT 21138_89-1-1-M-M-M
23	SEA 5	**57**	BT 21138_57-1-1-M-M-M	**90**	BT 21138_90-1-1-M-M-M
24	BT 21138_24-1-1-M-M-M	**58**	BT 21138_58-1-1-M-M-M	**91**	BT 21138_91-1-1-M-M-M
25	BT 21138_25-1-1-M-M-M	**59**	BT 21138_59-1-1-M-M-M	**92**	BT 21138_92-1-1-M-M-M
26	BT 21138_26-1-1-M-M-M	**60**	BT 21138_60-1-1-M-M-M	**93**	BT 21138_93-1-1-M-M-M
27	BT 21138_27-1-1-M-M-M	**61**	BT 21138_61-1-1-M-M-M	**94**	BT 21138_94-1-1-M-M-M
28	BT 21138_28-1-1-M-M-M	**62**	BT 21138_62-1-1-M-M-M	**95**	BT 21138_95-1-1-M-M-M
29	BT 21138_29-1-1-M-M-M	**63**	BT 21138_63-1-1-M-M-M	**96**	BT 21138_96-1-1-M-M-M
30	BT 21138_30-1-1-M-M-M	**64**	BT 21138_64-1-1-M-M-M	**97**	BT 21138_97-1-1-M-M-M
31	BT 21138_31-1-1-M-M-M	**65**	BT 21138_65-1-1-M-M-M	**98**	BT 21138_98-1-1-M-M-M
32	BT 21138_ 83-1-3-M-M-M-M-M	**66**	BT 21138_66-1-1-M-M-M	**99**	BT 21138_99-1-1-M-M-M
33	BT 21138_33-1-1-M-M-M	**67**	BT 21138-67-1-1-M-M-M	**100**	BT 21138_128-1--M-M-M
34	BT 21138_34-1-1-M-M-M				

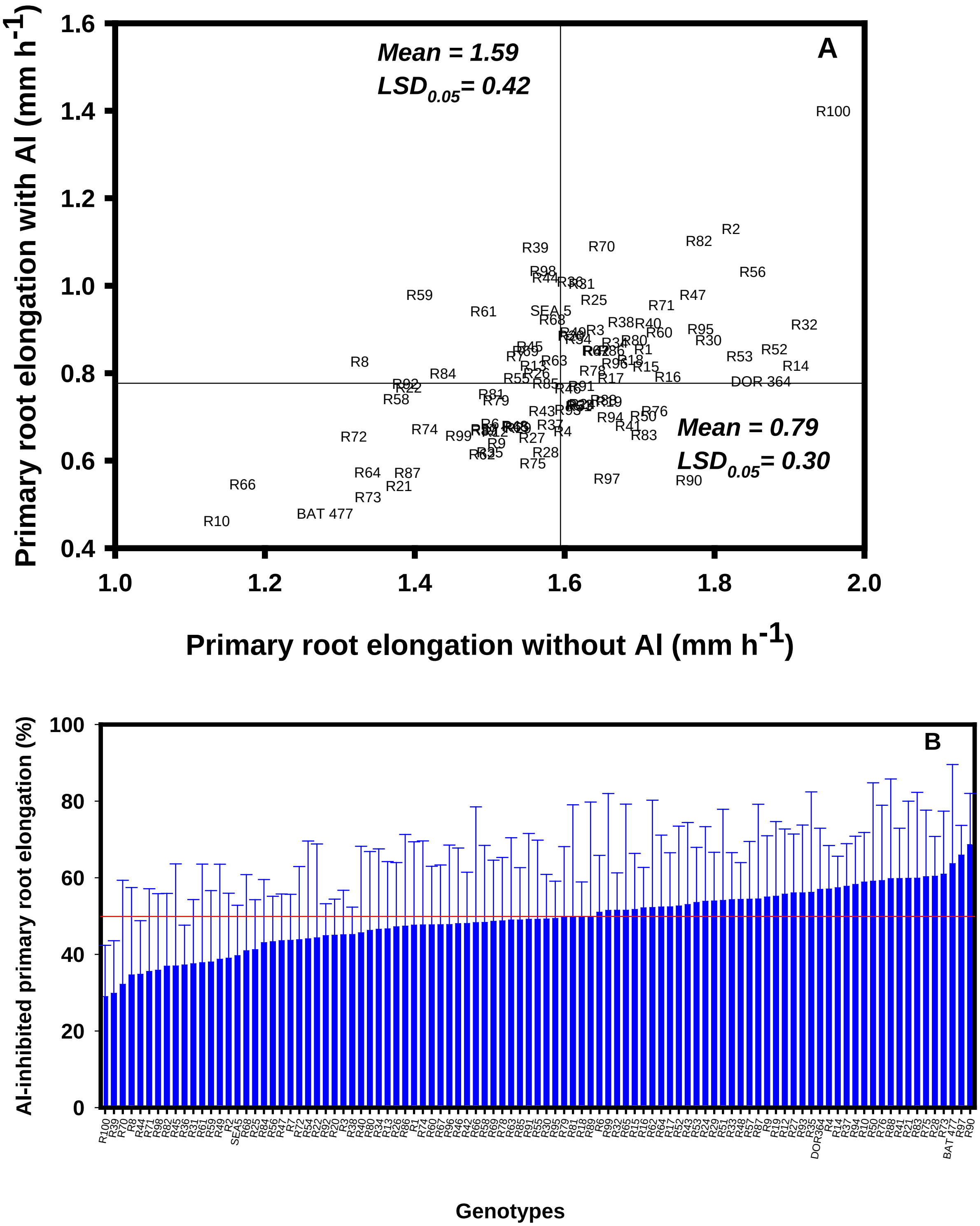

Figure 42. Root elongation rate (A, mm h^{-1}) and Inhibition of principal root elongation (B, %) of 100 common bean genotypes (98 RILs of DOR364xBAT 477 and 3 checks)evaluated in a solution containing 0.5 mM Ca, 0.5 mM K and 8 µM B with or without 20 µM Al for up to 48 h, pH 4.5. Bars are means ± SD of nine replicates from 3 experiments. Horizontal line represents the genotypic mean value.

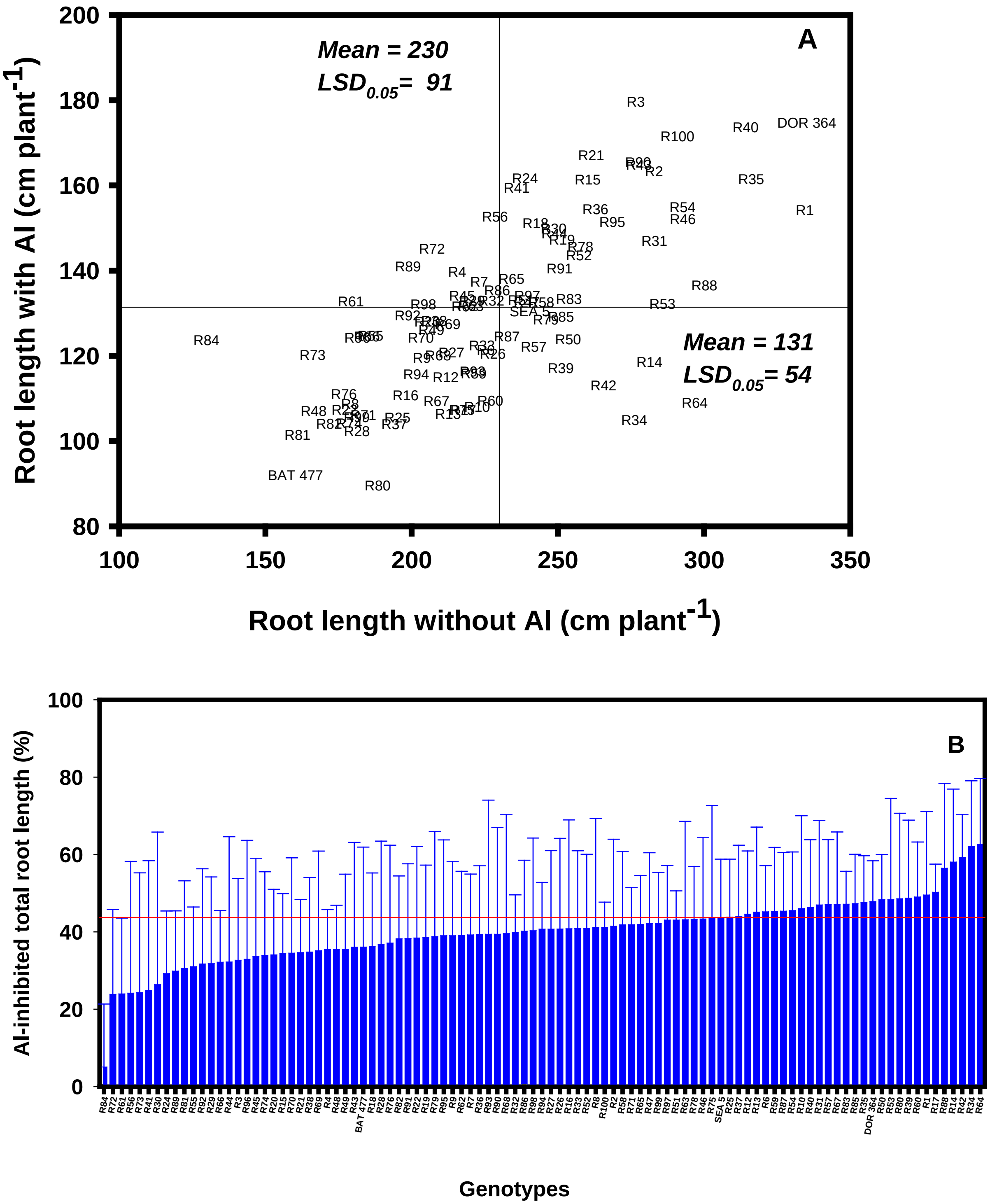

Figure 43. Total root length (A, cm plant^{-1}), and inhibition of total root length (B, %) of 100 common bean genotypes (98 RILs of DOR364 x BAT 477 and 3 checks) evaluated in a solution containing 0.5 mM Ca, 0.5 mM K and 8 µM B with or without 20 µM Al for up to 48 h, pH 4.5. Bars are means ± SD of nine replicates from 3 experiments. Horizontal line represents the genotypic mean value.

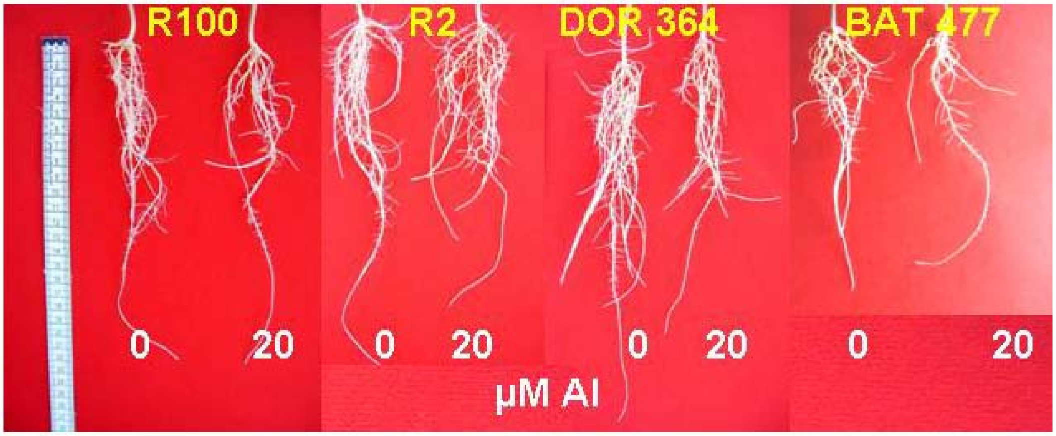

Figure 44. Root system of 2 selected RILs of DOR364 x BAT 477 and their parents after 48 h of exposure to a solution containing 0.5 mM Ca, 0.5 mM K and 8 µM B with 0 and 20 µM Al, pH 4.5.

Conclusions: Significant genotypic variation in resistance to aluminum in RILs of DOR 364 x BAT 477 was found. A few RILs with low inhibition of root growth under high Al in solution were identified. Two RILs (BT 21138_128-1-M-M-M and BT 21138_ 2-1-1-M-M-M) were found to be outstanding in root growth both with and without Al in solution.

Contributors: J. Ricaurte, R. García, F. O. Ibáñez, A. F. Rangel, S. Beebe, I. M. Rao (CIAT); W. Horst (Leibniz University of Hannover, Germany)

Activity 2.2 Developing germplasm with resistance to insect pests: Bruchids and leafhopper

Highlights :

- New accessions from the gene bank were evaluated for insect resistance
- Resistance to *Zabrotes subfasciatus* was reconfirmed
- New breeding lines that have resistance to the leafhopper (*Empoasca kraemeri*) were identified
- Some Andean bean lines presented high level of tolerance to *Empoasca* and less yield loss

2.2.1 Screening for sources of resistance to major insect pests

Rationale: Identification of sources of resistance to major insect pests of beans is a continuous activity. Additional work is conducted to identify and characterize the mechanisms of resistance to major specific pests.

Materials and Methods: Germplasm accessions and breeding lines are planted in the field under high levels of natural leafhopper infestation, usually with 4-5 replicates per genotype in randomized complete block designs. Evaluations for resistance include damage score and bean productivity ratings, insect counts, damage counts and in some cases, yield components and yields. In the case of *Zabrotes*, the combination of biochemical tests to confirm the presence of arcelin and insect feeding bioassays has given excellent results.

Leafhopper *(Empoasca kraemeri)*

No useful sources of resistance to the leafhopper were found among about 150 accessions of bean germplasm evaluated in 2008. In trials conducted under field conditions at CIAT headquarters, Mesoamerican parents with different resistance sources were evaluated with 240 lines in replicated nurseries. 26 of these lines were selected as resistant to be evaluated again in 2009 to confirm their resistance.

Storage weevil (*Zabrotes subfasciatus*)

In 2008, special emphasis was placed upon the reconfirmation of resistance in previously selected RAZ lines. These materials were later tested in nurseries with 3 repetitions with six pairs of Z*. subfasciatus* per 30 seeds. The genetic improvement method using backcrosses that combine biochemical tests to confirm the presence of arcelin and insect feeding bioassays have had satisfactory results whenever the resistance to the Mexican bean weevil (*Z. subfasciatus*) is to be incorporated into bean cultivars. It is necessary to reconfirm resistance in the RAZ lines with the objective of assuring purity of the obtained lines. Table 40 shows that the first lines generated maintain a high level of antibiosis in its control of *Z. subfasciatus.*

Contributors: J. M. Bueno, O. Díaz, J.F. Valor

Table 40. Levels of resistance identified to *Zabrotes subfasciatus* in RAZ lines

Line	Percentage of adult emergence	Days to adult emergence	Is[a]	Rating
RAZ 1	7.4	46.5	1.1	R
RAZ 4	6.8	44.2	0.9	R
RAZ 4-1	8.0	39.2	1.8	R
RAZ 4-2	9.6	43.4	2.0	R
RAZ 4-3	4.6	44.4	0.7	R
RAZ 4-5	9.5	45.0	2.0	R
RAZ 6	7.7	42.5	1.2	R
RAZ 7	6.7	47.2	1.0	R
RAZ 8	5.2	55.4	0.7	R
RAZ 9	8.3	46.7	2.0	R
RAZ 9-1	7.9	46.2	1.6	R
RAZ 9-4	8.6	49.6	1.5	R
RAZ 11-1	8.8	48.2	1.6	R
RAZ 12	5.4	48.8	0.8	R
RAZ 13-3	6.8	45.9	1.6	R
RAZ 13-4	6.9	44.9	1.3	R
RAZ 13-6	5.9	46.1	1.1	R
RAZ 14	12.0	42.4	2.8	R
RAZ 15	3.3	48.8	-0.1	R
RAZ 16	16.7	42.8	3.4	I
RAZ 17-4	12.7	45.0	2.3	R
RAZ 17-5	6.4	45.1	1.1	R
RAZ 17-10	13.3	47.2	2.3	R
RAZ 18-1	7.4	49.9	1.1	R
RAZ 20-1	16.8	44.9	3.5	I
RAZ 20-2	19.1	45.1	3.8	I
RAZ 24-4	14.2	45.9	3.0	R
RAZ 24-6	10.2	48.9	1.7	R
RAZ 24-7	12.2	46.1	2.8	R
RAZ 25-1	25.3	41.5	4.6	I
RAZ 25-8	14.2	42.9	3.2	I
RAZ 29	16.4	46.3	3.0	R
RAZ 31	24.2	45.2	4.0	I
RAZ 32	25.0	42.0	4.6	I
RAZ 34	1.2	47.3	-2.3	R
RAZ 36	1.2	51.8	-2.5	R
RAZ 45	5.8	52.5	0.7	R
RAZ 53	5.4	47.6	0.6	R
RAZ 59	6.3	46.6	0.8	R
RAZ 62	3.5	48.8	-0.5	R
RAZ 65	2.3	52.7	-1.5	R

Table 40. cont´d.

Line	Percentage of adult emergence	Days to adult emergence	Is[a]	Rating
RAZ 68	2.5	49.2	-0.8	R
RAZ 74	8.0	46.5	1.0	R
RAZ 82	2.3	49.5	-1.0	R
RAZ 84	7.9	48.1	0.9	R
RAZ 86	4.5	46.9	1.0	R
RAZ 87	5.8	50.7	0.6	R
RAZ 89	4.1	48.4	0.2	R
RAZ 92	6.6	48.9	1.2	R
RAZ 98	4.7	46.9	0.3	R
RAZ 109	8.3	47.4	1.6	R
RAZ 110	4.6	47.5	0.6	R
RAZ 114	13.3	48.4	2.0	R
RAZ 118	7.8	50.8	0.9	R
RAZ 119	6.4	49.1	1.2	R
RAZ 124	3.8	47.6	-0.4	R
RAZ 126	1.7	55.2	-1.7	R
RAZ 137	3.2	50.5	-0.4	R
RAZ 143	6.4	45.4	0.8	R
RAZ 167	15.6	49.7	2.6	R
RAZ 168	8.6	45.5	2.0	R
RAZ 169	16.0	46.6	3.3	I
RAZ 173	10.0	57.9	1.3	R
RAZ 193	2.0	63.1	-1.3	R
RAZ 136[b]	9.7	47.1	2.3	TR
RAZ 51	7.2	47.9	1.6	TR
ICA Pijao[c]	96.7	33.8	9.5	TS

[a] Index of susceptibility: (ln progeny per female/days to adult emergence) x 100;
[b] Resistant *P. vulgaris* line; [c] Susceptible *P. vulgaris* cultivar.

2.2.2 Developing germplasm resistant to insects

2.2.2.1 Storage weevils (*Zabrotes subfasciatus*)

Rationale: The identification of arcelin as a biochemical marker for the selection of progenies with resistance to *Z. subfasciatus* has greatly facilitated the incorporation of this trait into a range of cultivated beans. Using arcelin-1 donor parents in simple crosses or backcrosses to the cultivated parents we have been able to generate additional progenies (RAZ lines) that have shown high levels of resistance to Zabrotes. The purpose of this project was to evaluate the segregation of arcelin-based bruchid resistance in crosses of two RAZ lines with a red-mottled, drought tolerant Andean parent.

Materials and Methods: The work on the development of a molecular DNA microsatellite marker for arcelin presence and resistance to the Mexican bean weevil was as described in the 2003 Annual Report.
The crosses were made between the drought tolerant Andean breeding line SEQ1006 and RAZ 105 and

RAZ 106 as arcelin-donor parents in 2006 and advanced to the F_2 generation where all individuals were tested for the arcelin marker and the F_3 seed harvested from each single plant selection. The resulting 247 F_3 progenies from two different crosses were tested for resistance to *Z. subfasciatus* in replicated nurseries in the laboratory. The resulting F_3 progenies were used to reconfirm marker selection.

Results and Discussion: As shown in Tables 41 and 42, very high levels of resistance to the Mexican bean weevil were identified with absolute correspondence between the presence of arcelin and resistance to the insect.

Table 41. Levels of resistance to *Zabrotes subfasciatus* in F_3 seeds of progenies derived from crosses with RAZ 105

Cross	**Percentage of emergence**	**Days to adult emergence**	**Is**[a]
	Best lines selected for % emergence		
SEQ1006 x RAZ 105-32	0.0	79.0	-12.5
SEQ1006 x RAZ 105-49	0.0	79.0	-12.5
SEQ1006 x RAZ 105-66	0.0	79.0	-12.5
SEQ1006 x RAZ 105-94	0.0	79.0	-12.5
SEQ1006 x RAZ 105-18	1.2	60.3	-9.9
SEQ1006 x RAZ 105-116	1.2	75.7	-8.7
SEQ1006 x RAZ 105-21	1.3	69.0	-8.8
SEQ1006 x RAZ 105-77	1.4	71.7	-8.8
SEQ1006 x RAZ 105-50	1.8	63.0	-5.0
SEQ1006 x RAZ 105-38	2.1	59.7	-5.1
SEQ1006 x RAZ 105-54	2.8	57.0	-4.7
SEQ1006 x RAZ 105-24	2.9	70.1	-8.1
SEQ1006 x RAZ 105-104	3.2	59.0	-4.7
SEQ1006 x RAZ 105-46	4.2	56.7	-4.7
SEQ1006 x RAZ 105-80	4.8	56.7	-4.2
SEQ1006 x RAZ 105-20	5.0	65.7	-4.2
SEQ1006 x RAZ 105-44	5.5	59.7	-4.3
SEQ1006 x RAZ 105-30	5.5	57.2	-3.9
SEQ1006 x RAZ 105-4	5.6	57.7	-4.3
SEQ1006 x RAZ 105-45	5.6	47.0	-1.0
SEQ1006 x RAZ 105-37	6.2	55.4	-3.9
SEQ1006 x RAZ 105-65	6.3	57.5	-4.1
SEQ1006 x RAZ 105-61	7.4	60.8	-4.3
SEQ1006 x RAZ 105-85	8.1	51.7	-3.8
SEQ1006 x RAZ 105-10	8.6	43.7	-0.7
SEQ1006 x RAZ 105-23	9.6	50.2	0.6
	Checks		
RAZ 44[b]	9.7	48.4	1.5
RAZ 36[b]	0.0	79.0	-12.5
RAZ 193[b]	0.0	79.0	-12.5
RAZ 105[c]	10.4	42.9	2.8
ICA Pijao[d]	97.2	32.3	7.4
LSD	**24.7**	**14.4**	**6.0**

[a] Susceptibility Index: (ln progeny per female/days to adult emergence) x 100; [b] Resistant *P. vulgaris* line; [c] donor parents; [d] Susceptible *P. vulgaris* cultivar.

Table 42. Levels of resistance to *Zabrotes subfasciatus* in F_3 seeds of progenies derived from crosses with RAZ 106

Cross	Emergence Percentage	Days to adult emergence	Is[a]
Best lines selected for % emergence			
SEQ1006 x RAZ 106-132	0.0	71.0	-14.5
SEQ1006 x RAZ 106-35	1.0	63.0	-10.5
SEQ1006 x RAZ 106-137	1.5	68.0	-9.9
SEQ1006 x RAZ 106-87	1.8	54.3	-6.5
SEQ1006 x RAZ 106-120	2.6	57.3	-5.8
SEQ1006 x RAZ 106-148	2.7	58.0	-5.9
SEQ1006 x RAZ 106-146	3.1	56.3	-5.9
SEQ1006 x RAZ 106-18	3.2	64.8	-9.7
SEQ1006 x RAZ 106-54	3.3	62.3	-5.5
SEQ1006 x RAZ 106-124	3.3	50.7	-1.8
SEQ1006 x RAZ 106-83	3.7	54.3	-1.6
SEQ1006 x RAZ 106-119	3.9	56.0	-1.5
SEQ1006 x RAZ 106-8	4.0	56.0	-5.4
SEQ1006 x RAZ 106-44	4.1	59.2	-5.5
SEQ1006 x RAZ 106-106	4.1	57.3	-5.4
SEQ1006 x RAZ 106-75	4.4	62.7	-9.5
SEQ1006 x RAZ 106-74	5.4	50.0	-0.8
SEQ1006 x RAZ 106-31	5.7	49.2	-1.4
SEQ1006 x RAZ 106-122	6.4	47.8	-1.2
SEQ1006 x RAZ 106-23	6.7	51.4	-0.8
SEQ1006 x RAZ 106-133	7.2	50.9	-0.6
SEQ1006 x RAZ 106-149	7.4	47.3	-0.4
SEQ1006 x RAZ 106-88	7.6	54.2	-0.7
SEQ1006 x RAZ 106-67	8.0	47.5	-0.3
SEQ1006 x RAZ 106-32	8.8	51.3	-0.1
SEQ1006 x RAZ 106-82	8.8	51.2	-0.1
SEQ1006 x RAZ 106-80	8.9	51.1	-4.6
SEQ1006 x RAZ 106-28	9.2	49.8	-4.4
SEQ1006 x RAZ 106-76	9.2	59.1	-4.7
Checks			
RAZ 193[b]	0.0	71.0	-14.5
RAZ 36[b]	4.3	46.0	2.0
RAZ 44[b]	7.1	45.6	0.1
RAZ 106[c]	4.0	56.4	-0.4
ICA Pijao[c]	94.6	33.3	6.7
LSD	**47**	**22**	**14**

[a] Susceptibility Index: (ln progeny per female/days to adult emergence) x 100; [b] Resistant *P. vulgaris* lines; [c] donor parents; [d] Susceptible *P. vulgaris* cultivar.

Contributors: J. M. Bueno, M. Blair, J.F. Valor, C. Muñoz

2.2.2.2 Crosses to incorporate arcelin-based bruchid resistance into Andean beans

Rationale: The Arcelin resistance gene is the most effective resistance factor for the most common storage pests of common bean, namely the Mexican bean weevil, *Zabrotes subfasciatus* (Boheman). We have been making crosses between arcelin containing RAZ lines and a series of Andean and Mesoamerican beans with drought tolerance useful for Eastern and Southern Africa (Ethiopia, Kenya, Malawi, Tanzania and Zimbabwe). In addition we have been conducting marker assisted selection for the arcelin gene. The long-term objective of this work is to increase the efficiency of breeding for multiple constraint resistance and facilitate the pyramiding of bruchid resistance with other biotic and abiotic stress resistances.

Materials and Methods: Crosses were generated to incorporate Arcelin-based bruchid resistance into a drought tolerant background and then transfer that resistance/tolerance to the small white, Ethiopian variety Awash Melka and to various Andean bean types. The bruchid resistance sources used in the crosses were RAZ44, RAZ105, RAZ106, RAZ 107, RAZ168, RAZ169 and RAZ170, the first of these with small white grain type and the remainder all with large red mottled grain type. The drought tolerance sources were the DRK, RAA, SAB, SEA and SEQ lines described in other sections of the report as well as RCB588, RCB591, SER16, SER119, SXB405, SXB412 and SXB418 used in crosses with Awash Melka. In addition some triple crosses were generated for the nutrition breeding program using NUA35 and NUA56, and some double crosses were generated with the RMA lines discussed previously, the Malawian release CIM9314-34, the Kenyan releases KAT B1 and KAT B9 and other African released varieties, such as Canadian Wonder, CAL96 and CAL143. Marker assisted selection was carried out as described previously using microprep DNA.

Results and Discussion: For Andeans, a total of 251 F_1 plants segregated for the arcelin locus in Palmira 2008a (with 141 of these segregating for the arcelin locus alone and 110 segregating for both arcelin and the *bc3* gene). Of these 236 amplified with the arcelin marker and the proportion of resistant and susceptible genotypes are shown in Table 43. For Mesoamericans (Awash Melka), a total of 498 F_1 plants segregated for the arcelin locus in seven different pedigrees and the resulting resistant, susceptible and heterozygous selection are shown in Table 44.

Pedigrees of crosses with arcelin genes that have been advanced to the $F_{2:4}$ and $F_{1:3}$ generations appear in Table 45, including 16 simple crosses, 32 triple crosses and 60 double crosses.

Collaborators: M.W. Blair, H.F. Buendia, F. Monserrate, S. Beebe (SBA-1, CIAT)
T. Assefa (EARO, Ethiopia) J.M. Bueno, C. Cardona (Entomology)

Table 43. Selections made in 2008 b for the arcelin gene in triple and double crosses

Cross type	Arcelin	Segregation
Triple crosses	+	61
	-	101
Double crosses	+	20
	-	54

Table 44. Triple crosses used for marker assisted selection in the small white (navy) commercial class

Pedigree	No. of rows	R (+)	H	S (-)
AWASH MELKA x (RCB588 x RAZ44)	2	11	6	14
AWASH MELKA x (RCB591 x RAZ44)	4	24	11	38
AWASH MELKA x (SER119 x RAZ44)	4	27	9	47
AWAHS MELKA x (SER16 x RAZ44)	3	4	17	16
AWASH MELKA x (SXB405 x RAZ44)	5	42	14	43
AWASH MELKA x (SXB412 x RAZ44)	4	29	14	50
AWASH MELKA x (SXB416 x RAZ44)	5	44	4	31
Totals		**181**	**75**	**239**

Table 45. Simple, triple and double crosses with RAZ lines

Simple crosses	
BRB211 x RAZ170	RAZ107 x SAB576
BRB211 x RAZ169	SAB 568 x RAZ103
BRB263 x RAZ170	SAB 575 x RAZ105
BRB 264 x RAZ 104	SAB 581 x RAZ168
RMA68 x RAZ168	SEQ 1006 x RAZ 107
RMA69 x RAZ170	SEQ11 x RAZ170
RMA70 x RAZ167	SEQ1003 x RAZ170
RMA71 x RAZ105	SEQ1027 x RAZ104
Triple crosses	
RMA44 x (BRB264 x RAZ104)	(RMA 69 x RAZ 169) X NUA 35
RMA52 x (BRB215 x RAZ103)	NUA35 x (RMA70 x RAZ167)
RMA58 x (BRB264 x RAZ104)	NUA 35 x (BRB 264 x RAZ 105)
(BRB264 x RAZ105) x SAB630	NUA 35 x (BRB264 x RAZ104)
(BRB215 x RAZ 103) x SAB630	NUA 35 x (BRB 215 x RAZ 103)
(BRB264 x RAZ105) X SAB711	NUA56 x (RMA70 x RAZ167)
(BRB263 x RAZ169) X SAB 711	NUA56 X (SEQ1006 X RMX20)
(BRB285 x RAZ103) X SAB 711	NUA56 x (RMA70 x RAZ168)
(BRB285 x RAZ103) X SAB 711	(BRB215 x RAZ103) X SAB650
(BRB285 x RAZ103) X SAB 711	RAA19 X (BRB264 X RAZ105)
(RMA69 x RAZ169) X SAB 712	RAA20 x (BRB264 x RAZ105)
(RMA69 x RAZ169) X SAB 712	RAA21 x (BRB264 x RAZ105)
(RMA70 x RAZ169) X SAB 712	DRK149 x (BRB264 x RAZ104)
(RMA 70 x RAZ 168) X SAB 712	DRK149 x (BRB264 x RAZ105)
(BRB 285 x RAZ 103) X SAB 712	(BRB263 x RAZ169) X DRK 149
(BRB 215 x RAZ 104) X NUA 35	DRK156 x (BRB264 x RAZ105)

Table 45 cont'd.

Double crosses	
(CAL143 x SAB620) x (RMA70 x RAZ167)	(BRB266 x RMX19) x (SEQ1004 x RAZ167)
(CAL 143 x SAB 620) x (BRB 264 x RAZ 104)	(BRB268 x RMX19) x (SAB575 x RAZ104)
(CAL143 x SAB620) x (RMA70 x RAZ168)	(BRB215 x VAX6) x (RMA70 x RAZ168)
(SAB628 x CAL143) x (BRB285 x RAZ103)	(BRB215 x VAX3) x (RMA70 x RAZ167)
(SAB628 x CAL143) x (CMB106 x RAZ103)	(SAB617 x SAB621) x (SEQ11 x RAZ169)
(SAB628 x CAL143) x (DRK149 x RAZ103)	(CWONDER x SAB623) x (BRB285 x RAZ103)
(KATB1 x SAB625) x (BRB215 x RAZ103)	(CAL96 x SAB621) x (RMA69 x RAZ169)
(KATB1 x SAB625) x (BRB215 x RAZ104)	(CAL96 x SAB621) x (BRB264 x RAZ104)
(KATB1 x SAB618) x (BRB215 x RAZ103)	(BRB211 x VAX3) x (RMA69 x RAZ169)
(KATB1 x SAB618) x (BRB215 x RAZ104)	(SEQ11 X RAZ169) X (SAB621 X SAB635)
(KATB1 x SAB618) x (BRB263 x RAZ169)	(RMA70 x RAZ168) x (SAB621 x SAB635)
(KATB1 x SAB618) x (BRB263 x RAZ105)	(RMA71 x RAZ104) x (SAB621 x SAB635)
(KATB1 x SAB618) x (BRB263 x RAZ104)	(RMA71 X RAZ104) X (SAB617 X SAB621)
(KATB9 x SAB617) x (BRB215 x RAZ104)	(RMA70 x RAZ168) x (SAB620 x SAB631)
(KATB9 x SAB617) x (BRB263 x RAZ169)	(SAB620 x SAB631) x (RMA70 x RAZ167)
(KATB9 x SAB617) x (BRB264 x RAZ105)	(RMA69 x RAZ169) x (SAB620 x SAB631)
(KATB9 x SAB617) x (BRB264 X RAZ104)	(RMA68 x RAZ167) x (SAB620 x SAB631)
(KATB9 x SAB617) x (BRB215 x RAZ103)	(SAB617 x SAB621) x (BRB264 x RAZ105)
(KATB9 x SAB622) x (BRB285 x RAZ103)	(SAB617 x SAB621) x (BRB264 x RAZ104)
(KATB9 x SAB622) x (CMB106 x RAZ103)	(SAB620 x SAB634) x (BRB285 x RAZ103)
(KATB9 x SAB622) x (BRB264 x RAZ104)	(SAB617 x SAB621) x (BRB263 x RAZ169)
(SAB628 x KATB1) x (BRB285 x RAZ103)	(SAB617 x SAB621) x (BRB215 x RAZ104)
(SEQ1003 x BRB264) x (SEQ1027 x RAZ105)	(SAB616 x SAB629) x (BRB215 x RAZ103)
(BRB285 x RAZ103) x (SEQ1036 x RMX20)	(CIM9314-34 x SAB622) x (BRB215 x RAZ103)
(SEQ1036 x RMX20) x (BRB285 x RAZ103)	(CIM9314-34 x SAB622) x (BRB285 x RAZ103)
(RMA71 x RAZ104) x (BRB215 x VAX6)	(CIM9314-34 x SAB622) x (BRB264 x RAZ105)
(BRB215 x RAZ104) x (SEQ11 x RAZ169)	(CIM9314-34 x SAB622) x (BRB263 x RAZ169)
(BRB264 x RAZ104) x (SEQ1003 x RAZ169)	(CIM9314-34 x SAB622) x (SEQ11 x RAZ169)
(SEQ1003 x RAZ169) x (BRB264 x RAZ104)	(CWONDER X SAB623) X (RMA68 X RAZ167)
(BRB266 x RMA60) x (SAB568 x RAZ103)	(CWONDER x SAB623) x (SEQ11 x RAZ169)

2.2.2.3 Leafhopper (*Empoasca kraemeri*)

Rationale: Although there is little direct breeding for Empoasca tolerance today, routine evaluations of breeding materials is a service to the breeding programs to complement data on other traits. In 2008 support was given to the breeding program with the evaluation of resistance to the leafhopper in a large nursery of red, black, carioca, cream and white colored beans, with different resistances and agronomic characteristics (anthracnose, angular leaf spot, BCMV, BGYMV, CBB**,** drought**,** low fertility and high concentrations of grain iron).

Materials and Methods: Evaluations for resistance to *E. kraemeri* were done in the field under high level conditions of natural infestation. A randomized complete block design was used for this evaluation with 5 repetitions per genotype. Evaluations for resistance include a damage score and bean production rating, insect counts, damage counts and in some cases, yield and yield components.

Results and Discussion: Of the 232 evaluated entries, 1 was rated as resistant (damage scale of 6.5 or less in a 1 to 9 scale) and 25 as intermediate (damage scale of 6.6 to 7.0 in a 1 to 9 scale), with high infestation of 14.2 leafhopper nymphs per leaf at 50 days after planting (Table 46). The resistant line, SEN 62, is a black seeded line selected in the drought breeding project. Among the other lines with intermediate resistance, the AQB lines and the INB lines are interspecific progeny, derived respectively from *P. coccineus* and *P. acutifolius*. The SAB lines are Andean genotypes, also selected in the drought project. The selected lines will be reconfirmed in a field evaluation in year 2009.

Table 46. Leafhopper damage scores and reproductive adaptation score of best white, carioca, cream, black and red lines with high agronomic value in the VEF 2008.

Entry No.	Line	Seed color[a]	Seed size[b]	Leafhopper damage score [c]	Reproductive adaptation score[d]
6	AQB 608	CrSt	S	6.6	4.0
7	AQB 609	CrSt	S	6.8	3.8
154	INB 604	Bl	S	7.0	4.3
155	INB 605	St	S	7.0	4.0
156	INB 606	Bl	S	6.8	3.8
609	SAB 515	RSt	M	7.0	3.8
676	SAB 582	Wh	M	7.0	3.3
678	SAB 617	RSt	L	7.0	3.5
679	SAB 618	RSt	M	7.0	3.3
683	SAB 622	R	M	6.6	4.0
690	SAB 629	CrSt	M	7.0	3.5
698	SAB 637	RSt	M	7.0	3.3
704	SAB 643	RSt	M	7.0	3.8
707	SAB 646	RSt	M	7.0	3.5
842	SEC 18	RSt	M	6.9	5.8
843	SEC 19	Wh	S	6.9	4.3
846	SEC 22	Wh	S	7.0	5.3
853	SEC 29	Wh	S	7.0	4.8
911	SEN 57	Bl	S	7.0	4.3
912	SEN 58	Bl	S	7.0	5.3
913	SEN 59	Bl	S	7.0	5.0
914	SEN 60	Bl	S	7.0	4.5
916	SEN 62	Bl	M	6.4	5.8
919	SEN 65	Bl	M	7.0	5.3
920	SEN 66	Bl	M	7.0	5.0
922	SEN 68	Bl	S	7.0	4.8
1393	EMP 250	CrSt	M	5.5	6.8
1394	EMP 486	R	M	5.6	6.0
1395	EMP 512	CrSt	M	5.4	6.8
1396	EMP 547	Wh	M	5.8	6.3
1397	EMP 567	Wh	M	5.5	6.8
1398	EMP 576	Bl	M	6.1	5.5
1399	EMP 584	CrSt	M	6.0	5.8
1400	EMP 595	R	M	5.8	6.3
1401	BAT 41[e]	R	M	8.3	3.8
1402	ICA PIJAO[f]	Bl	M	6.5	6.0

[a] Wh= White; Bl = Black; Cr = Cream; St = Striped; R = Red; [b] S= small; M= medium; L= large; [c]On a 1-9 score scale (1 = no damage: 9 = severe damage); [d] On a 1-9 visual scale (1, no yield, no pod formation; 9, excellent pod formation and filling, excellent yield); [e] Susceptible check ; [f]Tolerant check.

Continuing with the search for resistance to leafhopper in 2008, 73 lines characterized by their resistance to drought and with the *bc-3* gene, low fertility and/or high iron with codes MAB, SQX, SBX, NEB, MIB, SER, SEN, INB, and AQB were evaluated for leafhopper damage. Nine selections were made under high levels of leafhopper infestation (12.4 nymphs per leaf at 50 days after planting) (Figure 45). The selected lines will be reconfirmed in a field evaluation in 2009. These reconfirmations will include a damage score and yield production rating, insect counts, damage counts and in some cases, yield and yield components. The selected lines are: NEB 31, MAB 84, SXB 119, AQB 149, MAB 159, SXB 175, SXB 184, SXB 192, MAB 335.

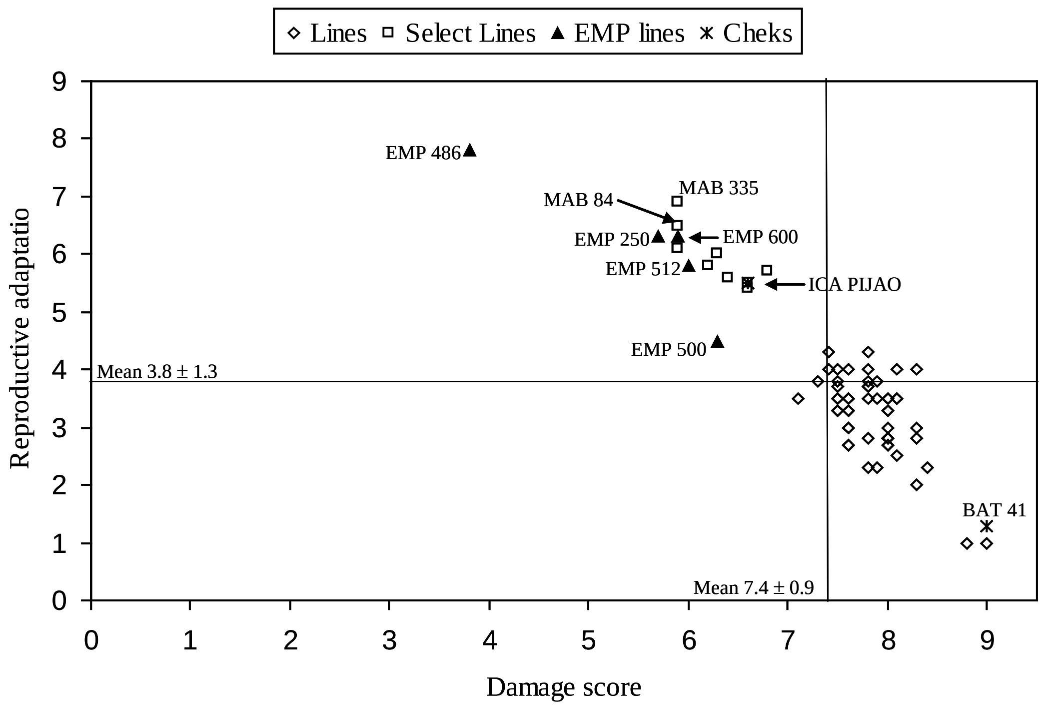

Figure 45. The relationship between damage scores and reproductive adaptation scores in 73 lines coded MAB, SQX, SBX, NEB, MIB, SER, SEN, INB, and AQB tested for resistance to *Empoasca kraemeri*

Contributors: J. M. Bueno, S. Beebe

2.2.2.4 Evaluation of Andean beans for resistance to leafhoppers

Rationale: Most progress in breeding for resistance to leafhopper has been performed with Mesoamerican beans. Special effort is needed to improve the resistance of Andean types that tend to be highly susceptible. In 2008, efforts were aimed at the development of Andean type beans with tolerance to the leafhopper, *Empoasca kraemeri*. In particular, Empoasca is a problem in warm, dry climates where bean golden yellow mosaic virus (BGYMV) is also prevalent, and thus combinations of these two resistances are desirable.

Materials and Methods: Red-seeded lines Andean genotypes with the *bgm-1* recessive allele for BGYMV resistance were evaluated for their resistance to the leafhopper. Evaluations for resistance to *E. kraemeri* were made in the field under conditions of high levels of natural infestation. A randomized complete block design was used for this evaluation with 5 repetitions per genotype. Evaluations for resistance include a damage score and bean productivity rating, insect counts, damage counts and in some cases, yield and yield components

Results: Table 47 shows lines that are better than ICA Pijao, the standard tolerant check. Five of these genotypes are more tolerant than their donor parents SEL 1428, SEL 1433, EMP 122, EMP 277 and EMP 320.

Table 47. Reconfirmed resistance to *Empoasca kraemeri* and yield of red lines with Andean genotypes crosses and corresponding parents.

Code	Damage score[a]	Reproductive adaptation score[b]	Yield (kg ha^{-1})		Percentage yield loss	Susceptibility index[c]
			Protected	Non-protected		
Crosses						
3438-39	6.7	4.3	1990.1	1457.9	27.8	1.3
3397-98-1	6.7	4.3	1828.0	1118.3	39.6	1.7
3397-98-4	6.7	5.3	1751.4	1620.9	7.9	0.7
3397-98-6	6.2	5.7	1694.6	1598.7	6.1	0.6
3397-98-8	6.8	5.3	1580.0	1222.2	23.1	1.2
3397-98-12	6.4	6.9	1572.2	1614.7	0.0	0.4
218759F2(M)W3	6.3	5.8	2086.1	1904.9	9.1	0.6
218757F2(M)W4	7.0	4.7	1670.5	1223.2	27.9	1.3
218757F2(M)W10	6.2	4.0	1727.0	1325.6	22.6	1.2
218757F2(M)W15	6.7	4.3	1414.0	1431.0	0.0	0.5
EMP lines						
EMP122[d]	6.8	4.3	1290.9	1029.1	21.0	1.2
EMP277[d]	6.8	4.3	1937.9	1451.6	24.8	1.2
EMP320[d]	6.8	5.3	1731.5	1516.2	13.9	0.9
EMP597	5.4	7.0	2099.1	2204.9	0.0	0.1
Checks						
SEL1428[d]	7.2	4.0	1326.2	1007.5	24.9	1.3
SEL1433[d]	7.8	3.0	1309.5	706.7	46.7	2.1
ICA PIJAO[e]	6.9	5.7	2264.1	1838.6	17.9	0.9
BAT 41[f]	8.6	3.0	1590.3	1086.6	30.8	1.5
LSD	**0.5**	**0.72**	**393.9**	**309.1**		

[a] On a 1-9 visual scale (1, no damage; 9, severe damage); [b] On a 1-9 visual scale (1, no yield, no pod formation; 9, excellent pod formation and filling, excellent yield); [c] Calculated with respect to the mean of the trial and the mean of the tolerant check; [d] Donor parents; [e] Tolerant check ; [f] Susceptible check.

Contributors: J. M. Bueno, M. Blair

Activity 2.3 Developing germplasm resistant to diseases

Highlights:

- A large number of crosses were made to pyramid insect (bruchid) and disease (BCMNV and CBB) resistance with drought tolerance or mid-elevation adaptation in Andean bush beans. The arcelin gene was used as the source of bruchid resistance and was effectively selected for in 115 different cross combinations. Meanwhile, 187 cross combinations were generated for disease resistance. These crosses are being advanced at our drought stress and mid-elevation sites in Colombia.
- Twelve new, large seeded red mottled bean varieties with multiple resistance to diseases and up to 30% better yield compared to commercial varieties released in six countries in eastern Africa.
- Thirteen new red kidney varieties combining multiple stress resistance with high yield potential and marketable grain characteristics are released in seven countries in east and central Africa.
- Eight new speckled sugar varieties with multiple disease resistance, marketable grain types and high yield potential (up to 24% over commercial checks) released for smallholder production in four countries in eastern Africa.
- Eight new small and medium red bean varieties combining multiple disease resistance, high yield potential and marketable grain characteristics released for smallholder production in three countries of eastern Africa.
- Eighteen new tan, brown and yellow seed varieties with multiple resistance to diseases and high yield potential released for production by smallholder farmers in four countries in eastern Africa
- Twenty-six new climbing bean varieties combining multiple resistances to diseases with high yield potential and marketable grain characteristics released for smallholder production in seven countries in east and central Africa.
- Several segregating populations and fixed lines in different market classes from South Africa, Malawi and Tanzania are available for distribution to interested NARS partners within SABRN and others in Africa
- From the regional breeding program 24 (brown/khaki), 73 (sugar) and 213 (red mottled) developed for resistance to angular leaf spot, or common bacterial blight or low soil fertility or a combination of these stresses were distributed to various NARS programs.
- Twenty-nine lines in various market classes which were developed for rust resistance or a combination of rust and angular leaf spot or rust and halo blight resistance by the NARS in South Africa were sent to the SABRN coordinator for seed increase and onward distribution to other interested NARS for the next planting season.
- Twenty four new lines with a resistance gene to *Pythium* root rot were identified and included in the *Pythium* root rot nursery.
- Forty lines combining resistance to *Pythium* root rot and angular leaf spot were identified and available for sharing with partners

2.3.1 Crosses to incorporate BCMV and CBB resistance into Andean beans

Rationale: Bean common mosaic necrosis virus (BCMNV) is an aphid and seed transmitted Potyvirus that is very important in Eastern and Southern Africa where it causes necrotic symptoms on *I* gene containing genotypes. The related virus BCMV causes typical potyvirus symptoms on susceptible genotypes that do not contain the *I* gene. Both BCMV and BCMNV resistance is very important in dryland areas of Africa were aphid vectors are common. The most appropriate resistance combination is the *I* gene with a recessive resistance gene *bc-3* which protects *I* gene containing genotypes from necrosis or the *bc-3* gene alone due to its wide spectrum of resistance. Another important disease in the region is common bacterial blight (CBB) which is a foliar and seed-borne disease of beans grown in most tropical lowland and subtropical areas of production especially during hot, humid summer weather. The disease is caused by the pathogen *Xanthomonas axonopodis* pv. *phaseoli* (Xap), which is widespread and part of a complex of Xanthomonad bacterial pathogens attacking many broadleaf and vegetable crops. Resistant bush beans were developed to both of these diseases in CIAT in the 1990s but have not been widely deployed in Andean breeding lines. As both diseases are important constraints in the same areas where drought occurs, it has been our goal to pyramid resistance to both diseases together with drought tolerance. This project describes the crosses made so far for this goal and outlines the initial attempts at pyramiding through marker assisted selection.

Materials and Methods: Hybridizations were made in CIAT greenhouses between commercial Andean seed types and drought tolerance genotypes (SEA, SEQ, SAB lines) with sources of bean common mosaic necrosis virus resistance (BRB lines), common bacterial blight resistance (VAX, RMX lines) and arcelin-based bruchid resistance (RAZ lines). F_1 seed was then planted in the Darien 2007b for triple and double crosses. These F_1 in turn were planted in Palmira 2008a so as to make gamete selections that were used for marker validation using the markers ROC11 for BCMNV resistance, SU91 for CBB resistance and two new microsatellites associated with bruchid resistance. The Andean parents were from the red mottled, cream mottled, yellow and large red commercial classes, namely AND277, AND279, Canadian Wonder, CIM 9314-3, CMB106, CMB107, KATB1, KATB9, RMA44, RMA46, RMA52, RMA58, RMA60, RMA63, RMA66, RMA68, RMA69, RMA70, RMA71, RMA72, RMC57, RMC58, RMC65. The specific CBB resistant lines were VAX3, VAX6, RMX2, RMX8, RMX19, RMX20; while the BCMNV resistant lines were BRB198, BRB211, BRB263, BRB264, BRB265, BRB 266, BRB267, BRB268. The drought tolerant parents were DRK149, DRK156, RAA21, RAA34, SAB514, SAB516, SAB560, SAB568, SAB575, SAB576, SAB581, SAB630, SEA5, SEQ11, SEQ1003, SEQ1004, SEQ1006, SEQ1027, SEQ1032. Finally the arcelin containing parents were RAZ105, RAZ106, RAZ 107, RAZ168, RAZ169 and RAZ170.

Results and Discussion: A total of 196 multiple F_1 combinations were generated (88 from triple crosses and 108 from double crosses). Examples of these are given in Tables 48 and 49. In addition, 91 other F_1 combinations from simple crosses (28 with BCMNV genes, 31 with CBB genes and 32 combining drought tolerance from SAB lines with larger seed size) were made and advanced to the $F_{2:3}$ generation. Most of the combinations target Andean seed classes (red mottled, large red).

Table 48. Examples of triple crosses combining BCMV, CBB or insect resistance genes together with drought tolerant and non-drought tolerant Andean parents.

For mid-altitude adaptation	For drought tolerance
RMA44 x (BRB264 x RAZ104)	RAA20 x (BRB264 x RAZ105)
RMA44 x (BRB215 x VAX6)	RAA20 X (BRB211 X VAX3)
RMA44 x (BRB264 x VAX3)	RAA21 x (BRB264 x RAZ105)
RMA44 x (BRB214 x VAX3)	RAA21 X (BRB211 X VAX3)
RMA44 x (BRB265 x VAX6)	DRK149 x (BRB264 x RAZ104)
RMA52 x (BRB266 x RMX19)	DRK149 x (BRB264 x RAZ105)
RMA52 x (BRB215 x RAZ103)	DRK156 X (BRB211 X VAX3)
RMA58 x (BRB266 x RMX19)	DRK156 x (BRB264 x RAZ105)
RMA58 x (BRB264 x RAZ104)	(BRB264 x RAZ105) x SAB630
RMA58 x (BRB268 x RMX19)	(BRB215 x VAX6) x SAB630
RMA58 x (BRB211 x VAX3)	(BRB215 x RAZ 103) x SAB630
RMA60 x (BRB214 x VAX3)	(BRB214 X VAX3) X SAB630
RMA60 x (BRB266 x RMA60)	(BRB215 X VAX6) x SAB645

Table 49. Examples of double crosses combining BCMV, CBB or insect resistance genes together with drought tolerant and non-drought tolerant Andean parents.

(SAB619 X CAL143) X (BRB214 X VAX3)	(CAL143 x SAB620) x (BRB264 x RAZ105)
(SAB619 X CAL143) X (CMB106 X VAX3)	(CAL143 x SAB620) x (RMA70 x RAZ167)
(SAB619 X CAL143) X (BRB215 X VAX6)	(CAL143 x SAB 620) x (BRB264 x RAZ104)
(SAB628 x CAL143) x (BRB285 x RAZ103)	(CAL143 x SAB620) X (BRB264 X VAX3)
(SAB628 x CAL143) x (CMB106 x RAZ103)	(CAL143 x SAB620) x (RMA70 x RAZ168)
(SAB628 x CAL143) x (DRK149 x RAZ103)	

Marker assisted selection was used on a total of 383 gametes developed from BRB lines containing the *bc-3* resistance gene, and 79 gametes developed from VAX lines containing a CBB resistance QTL. Some of the gametes for BCMV resistance (110) also segregated for arcelin-based insect resistance effective against the bruchid, *Zabrotes subfasciatus*. The ROC11 based selection was carried out with alkaline extraction DNA and agarose gel multiplexing as described previously, while the SU91 evaluation was performed with a mixture of different dilutions of alkaline extraction or miniprep DNA without multiplexing which made it more time consuming and expensive to carry out.

Collaborators: M.W. Blair, F. Monserrate, A. Hincapie, S. Beebe

2.3.2 Development and release of new red mottled bean varieties with multiple constraint resistance in eastern Africa

Rationale. The large seeded red mottled bean is probably the most important market class in East and Central Africa and in major bean producing countries in southern Africa such as Malawi. Red mottled beans are an important grain type in west and central African countries such as Cameroon. Red mottled beans command an estimated 22% market share of bean markets in East, Central and Southern Africa. An estimated 740,000 ha are sown with red mottled bean in Africa annually. Despite the rapid growth in demand for red mottled bean, supply has not kept pace in some countries. For example, Kenya is net importer of red mottled bean. Attempts to increase productivity have been severely constrained by biotic and abiotic stresses. Major biotic stresses include angular leaf spot, anthracnose, root rots and common bacterial blight. The most important abiotic stresses in red mottled bean growing areas are low soil nitrogen, phosphorus, soil acidity and frequent droughts. Kenya, Uganda, Tanzania and Malawi are not only the leading producers of red mottled beans but are also major consumers. Red mottled bean is gaining popularity in other countries in the region. For example, red mottled is now a popular grain type in southern Ethiopia since its introduction in the area in 1999/2000. In Awassa, the red mottled bean was selling at a higher price in local markets (20 to 30 Birr per kg, equivalent to US$ 2 to 3) five years after introduction, compared to the traditionally popular small red (CIAT, 2004). However, most of the regionally important red mottled commercial cultivars such as GLP 2 (Rosecoco), K20, K132 and Lyamungu 85 are susceptible to diseases, pests and low soil fertility (CIAT, 2005). This has contributed to decline in national production and low yields in farmers fields, adversely affecting food security, nutrition and incomes of bean growers in the region. A regional program was started in 2001 to develop improved red mottled bean lines with resistance to diseases (especially angular leaf spot, anthracnose, common bacterial blight and root rots) and tolerance to abiotic stress factors especially low soil fertility and drought. Development of the new varieties involved assembling a working collection, identification of sources of resistance, development of breeding populations, identification of lines combining resistance to two or more biotic and abiotic stresses, regional evaluation of promising lines and release of varieties. Since 2000, the regional program adopted a decentralized market-led breeding strategy with responsibilities shared among the nine network member countries (CIAT, 2001; Kimani, 2005). Regional breeding activities for red mottled grain type were based at Namulonge in Uganda and Kabete in Kenya. This report highlights milestones realized by this program towards development of a new generation of red mottled bean varieties in eastern Africa.

Materials and Methods:

Working Collection. A breeding collection, which comprised of segregating populations, advanced breeding lines and other sources of resistance to angular leaf spot, anthracnose, root rots and tolerance to low soil phosphorus and nitrogen was created at Kabete. The collection included materials from CIAT-Colombia, Kenya and CIAT-Uganda.

Sources of resistance. Potential parents for the crossing program were identified from old and current commercial cultivars contributed by national programs. Sources of resistance originated from previous germplasm evaluations for biotic and abiotic stresses in Africa and Colombia. Mexico 54, G5686 and BAT 332 were used as donors for resistance to angular leaf spot, G2333 and NB 123 for anthracnose, POA 2 and FEB 190 for common bacterial blight, GLP 92 (Mwitemania) for resistance to halo blight, SCAM 80 CM/5, L226-10 and RWR 719 for root rots, and RWR 2075 and RWR 1946 for tolerance to low soil fertility, and L226-10 for bean common mosaic virus. L226-10 is resistant to rust, bean common mosaic virus (BCMV), angular leaf spot and several root rots (Freytag et al., 1985). RWR 2075 and RWR 1946 are also resistant to root rots (Namayanja et al., 2003). Characteristics of other parental lines are shown in Table 50.

Population development. A multiple stress breeding approach based on multi-parent crosses was used to create breeding populations (Singh, 1994). Backcrosses and simple crosses to correct specific deficiencies for simply inherited resistances also were made at Kabete and Namulonge. Complex crosses were made to combine single resistances from selected parental lines. Three sets of populations were created: KP 01, KP 86 and KP04. KP01 was developed from bi-parental and multi-parent crosses among 51 genetically diverse lines from Andean and Middle-American gene pools. The parents included lines with known resistance to angular leaf spot, anthracnose, common bacterial and other diseases and tolerance to low soil fertility. KP 86 was derived from a seven parent complete diallel cross at Kabete. It was used to generate 33 F_2 populations. KP04 was derived from bi-parental crosses among recent sources of resistance and popular commercial varieties. This population was designed to correct deficiencies of the commercial parents.

Selection for resistance from KP01 populations. Selections were made for resistance to angular leaf spot, anthracnose, common bacterial blight, bean common mosaic and necrotic viruses (BCMV/BCMNV), rust and plant type in the early generations (F_2 to F_4). Both artificial inoculations and natural epiphytotics were used to identify resistant genotypes. Fifty-two segregating populations from KP 01 and lines from other crosses were advanced to F_4 generation at Kabete Field Station and subjected to natural epiphytotics of angular leaf spot, root rots, anthracnose and rust. F_2 plants were advanced as progeny rows in F_3 and F_4. Selection criteria included growth habit, reaction to diseases, vegetative vigour, pod load and seed characteristics. Seed harvested from F_4 plants was separated into seven market classes (red mottled, dark red kidneys, small reds, yellow and brown, sugars, carioca and pintos). Seed of each market class was divided into four parts. The first part was screened for tolerance to angular leaf spot and *Pythium* root rot under artificial inoculation at Kawanda; the second part was screened in a field plot heavily infested with root rots in Sabatia. A third part was grown in low soil phosphorus test site in Kakamega, in Western Kenya, for soil acidity at Mulungu Research Station in Kivu province (D. R. Congo), and for tolerance to low soil nitrogen at Selian Agricultural Research Institute (Tanzania). These low soil fertility screening sites were selected by the Bean Improvement for Low soil Fertility (BILFA) working group (Lunze et al., 2007).

Table 50. Characteristics of some parental lines used in multi-parent crosses.

Line	Seed color	Seed size	*Growth habit	Anthracnose	Common bacterial blight	Angular leaf spot
PVA 800A	Red mottled	medium	IIB	2	7	4
ICA Quimbaya	red	large	I	2	7	7
XR-12307-1	red	small	III	-	1	-
Catrachita	red	small	III	2	8	7
AND 277	red	medium	I	3	5	4
A222	black	small	II	4	9	3
G16140	Gray stripped	large	III	1	7	3
AFR 188	red	medium	I	2	4	5
G10613	white	small	III	2	7	5
XAN 309	red	small	IIB	7	3	7
G5686	Yellow mottled	large	I	2	8	2
A193	Red mottled	large	II	2	3	3
MAR 3	pinto	small	III	2	5	2
G5653	pink	small	III	2	8	4
PVA 1111	red	large	I	2	7	4
AFR 612	Red mottled	medium	I	2	5	4
BRB 190	Red mottled	medium	I	2	7	3
MAM 48	pinto	medium	III	7	5	3
CAL 167	Red mottled	medium	II	7	6	3
ICA Tunduma	Red	large	II	-	7	3
AND 279	Red mottled	medium	I	2	7	3
CAL 143	Red mottled	medium	I	2	6	4
Calima	Red mottled	large	I	5	5	4

* Growth habit : I=determinate, upright; II= semi-determinate, III= semi-climber. Disease scores: 1-3= resistant, 4-6= intermediate and 7-9=susceptible.

Selection from KP86 populations. The segregating populations were selected for eight generations for resistance to six diseases (rust, angular leaf spot, anthracnose, halo blight, BCMV and common bacterial blight), yield and seed characteristics both in the greenhouse and in the field. Disease assessment was based on artificial inoculations and natural epiphytotics in the field. Disease assessment was done 21 days after inoculation (R6) and also at mid-pod filling (R8). Susceptible plants were discarded. To determine the yield potential of early generation lines, more than 200 F_4 and F_5 lines were evaluated at five locations for two seasons.

Selection from KP04 Populations. Eleven F_2 populations segregating for red mottled grain types and resistance to diseases were developed from the KP04 crosses (KAB02, KAB 03, KAB 04, KAB05, KAB06, KAB 07, KAB10, KAB11, KAB12, KAB 13 and KAB 14) (CIAT, 2005). Single plants were selected from F_2 populations grown at Thika and Kabete during long rain (LR) season (April to August). The selected plants were used to establish $F_{2.3}$ progeny rows at Kabete and Thika during short rain (SR). Plants were rated for diseases, phenology, grain yield and other agronomic traits using the CIAT standard scale (Schoonhoven and Pastor-Corrales, 1987). Susceptible plants were discarded. Resistant plants within a progeny row were bulk-harvested and evaluated in replicated trials at the two locations during the LR ($F_{2.4}$) and SR ($F_{2.5}$) seasons. $F_{2.5}$ generations were screened for angular leaf spot at Kabete and root rots in an infested field in Sabatia (western Kenya), and at a disease hotspot in Laikipia (Rift Valley region).

Line development. One hundred red mottled lines selected from KP01 were evaluated in major agro-ecological zones in Uganda, Ethiopia, D. R. Congo, Cameroon, Kenya, Rwanda and Tanzania between 2004 and 2008 to identify lines with broad and country specific adaptation both on-station and in farmers' fields. Regionally important red mottled commercial cultivars were included as checks. The trials were laid out in lattice design with three or four replicates. Each plot had four, 5 m rows. Agronomic data was collected from the inner two rows. Intra-row spacing was 10 cm and 45 between rows. Rating for biotic and abiotic stresses followed CIAT (1987) standard system. Collaborators added other promising red mottled lines to the standard set (25 entries) for comparison.

Fifty-one lines were selected from KP 86 populations and evaluated in advanced yield trials at 10 locations for three seasons. Four commercial varieties (GLP2, GLP 24, GLP 92 and GLP 1004) were included as checks. Twenty-one lines were selected for participatory on-farm evaluations in eight locations for two seasons. They were distributed as a regional nursery.

Two hundred eighty one $F_{2.6}$ lines selected from seven KP04 populations were evaluated in preliminary and intermediate yield trials at Kabete, Laikipia and Ol Jorok (Kenya). The 281 $F_{2.6}$ lines were originated from seven of the 11 populations: KAB 02 (67 lines), KAB 05 (16 lines), KAB 06 (70 lines), KAB 12 (25 lines), KAB 10 (47 lines), KAB 11 (30 lines) and KAB 13 (26 lines). These lines were previously selected for resistance to diseases, plant type and other agronomic traits for five generations at Kabete, Sabatia, Ol Jorok and Laikipia field sites in Kenya.

Variety release. Each country selected candidate varieties from the regional nurseries for final evaluations and variety released based on the national variety release procedures.

Results and Discussion

Reaction to Diseases

Natural epiphytotics facilitated elimination of plants and progeny rows susceptible to angular leaf spot, anthracnose, rust, and common bacterial blight in F_2, F_3 and F_4 at Kabete (1860 masl). However, the severity of diseases varied with seasons. Root rots occurred sporadically especially after the heavy rains. In Kawanda, 453 lines were inoculated with Mesoamerican and Andean races of *Phaeoisariopsis griseola* in a screenhouse. One hundred seventy-two lines were resistant to Mesoamerican races; 173 showed intermediate reactions and 86 were susceptible. When inoculated with Andean races, 184 lines showed resistant reactions, 99 were intermediate and 148 were susceptible. Both Andean and Mesoamerican races and their intermediates occur in many bean growing areas in East and Central Africa. However, Andean races are more widespread. Results showed that 143 lines were resistant to races from the two gene pools. Table 51 shows some of the genotypes with combining resistance to races from the two gene-pools. Two lines NM 12667-4A-1 and UBR (93)22-5-1 had no disease after inoculation with the two race groups. NM 12667-4A-1 was selected from the cross (PVA 773 x ICA Tunduma)F_1 x(PVA 800A x((XAN 309 x A193)F_1 x(MAR3 x G5653)F_1) . ICA Tunduma, PVA 800A, A193, MAR 3 and G5653 are resistant to angular leaf spot (Table 50). This suggested that NM 12667-4A-1 may have several alleles conditioning resistance to races of Mesoamerican and Andean *Phaeoisariopsis griseola*.

Table 51. Disease scores for the best lines selected from the segregating populations and other nurseries at Kawanda under artificial inoculation with Mesoamerican and Andean races of *Phaeoisariopisis griseola*.

Lines	Mesoamerican	Andean
NM 12667-4A-1	1	1
DOR 676-1	1	1
L R K 32	1	1
NR 12632-3D-1	1	1
FEB 191-1	1	1
K28/13A I-1-1	1	1
VTTT 915/11-2	2	1
OBA 3-1	1	1
NR 12638-7C-1	2	1
NR 12638-3B-1	1	1
NR 12636-4A-2	2	1
NR 12634-13	1	1
NR 12631-12	1	1
NR12793-6 B	1	1
UBR(93)22-21-1	1	1
VTTT 915/7	1	1
BOA 5-8/2	2	1
Checks		
VTTT 918/11-1	9	9
VTTT 919/8-1	9	9
VTTT 919/10-2	9	9
VTTT 919/16-2	9	9
VTTT 920 /10-1	9	9

A total of 715 lines were artificially inoculated with *Pythium* spp at Kawanda. Results showed that three lines were resistant, 239 intermediate and 473 were susceptible. Promisnig lines are presented in Table 52. *Pythium* spp. are frequently the initial incitant of root rots in bean growing areas of East and Central Africa. Outstanding lines resistant to *Pythium* were NR 12631-7-1, NM 12657-5C-2 and NM 12646-3-1. All were derived from multi-parent crosses. Three hundred lines were screened for resistance to root rots in a field plot heavily infested with the disease in Sabatia. Twenty-five lines succumbed to the disease and produced no seed. All the other lines produced seeds which varied from 0.5 to nearly 400 g m^{-2}. Table 53 shows that the best lines produced significant amounts of seed despite heavy disease pressure. Outstanding lines included selections from RAB 475, DFA 62, NR 12797-8-1, NR 12633A-6-1, NR 12633-5-1 and NM 12805-7C-1. These lines produced over 300 g m^{-2}. The results showed that some of the outstanding lines in greenhouse and field screening originated from the same crosses: NR 12631, NM 12657, NM 12646 and NR12633 (Tables 52 and 53). Mortality among the best lines ranged from 0% (DFA 62-1 and NM12646-3-1) to 48% (NR 12656-8A-1). A total of 275 lines were selected for further evaluation. These represented not only the red mottled class but another four commercial classes as well. The methodology described here is relevant for those classes, especially the red kidney class.

Table 52. Disease scores of selected red mottled and red kidney lines artificially inoculated with *Pythium* spp at Kawanda Agricultural Research Institute, Uganda.

Line	Mean
NR 12631-7-1	2.8
NM 12657-5C-2	2.9
NM 12646-3-1	3.0
NR 12632-3G-2	3.1
NR12633-11[a]	3.1
NR 12793-8-1	3.2
AND 1056-1	3.3
DOR 703	3.3
NM 12803-11	3.3
NR 12 638-7B	3.3
RWR1873	3.3
RWR 719	3.4
NR 12633-5-1	3.4
RWK 10	3.4
NR12633-4E-1	3.5
P 94056	3.6
NR 12797-8C-1	3.7
NR 12638-10-1	3.7
NR 12634 -1B-1	3.8
NR 12633-5B-1	3.8
AND 1055-1	3.8
POA 8-1	8.8
RWR 10	9.0

Table 53. Seed yield and percent morality of bean lines selected in a field plot infested with root rots in Sabatia, Western Kenya.

Line	Percent mortality	Seed yield (g m^{-2})
RAB 475-1	15	399
DFA 62-1	0	385
NR 12797-8-1	10	336
NR 12633 A-6-1	36.8	319
NR 12633-5-1	27.7	305
NM 12805-7C-1	25	300
NR 12631-3D-1	26.3	299
NM 12652-9-1	10	293
NM 12806-2A-1	16	286
AND 1055-1	10	282
NR 12657-12	20	274
NR 12634-1C-1	35	262
NR 12649-B-1	31.5	253
NM 12651-9-1	30	250
NR 12631-9	16	250
NM 12651-116-1	15	246
RWR 1742-1	17.6	244
NM 12651-14-1	20	242
NM 12646-3-1	0	231
NR 12656-8A-1	48	224

Adaptation to low soil P, N and pH

Red mottled lines with tolerance to low P and low pH were AFR709-1, NM 12650-4C, AND 932-1 and NR 12631-9. The lines AND 932-1, VTTT 919-1, AFR 709-1 and NM 12650-4C combined tolerance to low soil acidity and low N. Seven red mottled lines combined tolerance to low soil P and N. These were AFR 709-1, NM 12656-6-1, AND 932-1, NM 12650-4C, NM 126-2A-1, NM 12805-7C-1 and NM 12655-3-1. Three red mottled lines were tolerant to all three stresses: AFR 709-1, AND 932-1 and NM 12650-4C.

Evaluation of advanced lines

In Uganda, seven lines were selected. These were ECAB 0060, ECAB 0070, ECAB 0090, AFR 623, POA8, F7MG/1 and POA 4. POA 4 was released as NABE 4.

Based on on-station and on-farm evaluations for two seasons, 15 lines were selected in D. R. Congo from the regional multiple constraint nursery. These included CAL 143, AND 907, AND 897, AND 1060, AFR735, AFR 699, UBR93/4, AND 1005, POA 2, CAL 175, CAL 172, VAC 49, POA 8, AFR 623 and CAL 176. The regional nurseries were also distributed for further evaluation and selection in M'vuazi and Equator regions in western DRC. Selections from western D. R. Congo were further distributed to countries in West and Central Africa Bean Research Network (WECABREN) in 2006, 2007 and 2008.

In southern Ethiopia, ten lines produced higher yields compared regional commercial varieties (K132 from Uganda, CAL 143 from Malawi, GLP 2 from Kenya and Lyamungu 85 from Tanzania). Yields varied from 2018 kg ha^{-1} for the local check to 3321 kg ha^{-1} for ECAB 0027 (Table 54). Growing conditions were favourable and no major disease incidence was recorded. The best yielding lines were ECAB 0027, ECAB 0008, ECAB 0081, ECAB 0063, ECAB 0042, ECAB 0043, ECAB 0098 and ECAB 0019. In Rift Valley region of Ethiopia, selected lines were evaluated in multi-location trials and are in the final stages of release.

In Madagascar, two red mottled lines were selected. Yields were lower in Madagascar compared to other sites. The best performing lines were ECAB 0034 (890 kg ha^{-1}) and ECAB 0063 (866 kg ha^{-1}).

Based on performance at three locations over two seasons, the best performing red mottled lines in Kenya were: ECAB 0019, ECAB 0027, E8, ECAB 0063, ECAB 0041, ECAB 0060, ECAB 0023, ECAB 0081, ECAB 0098, ECAB 0013, ECAB 0097, ECAB 0056, ECAB 0043, ECAB 0008, ECAB OO20, ECAB 0047 and ECAB 0068 (Table 55). These results indicate that most of the lines performed well in more than one country, indicating broad adaptation. Two outstanding lines were selected at sites in four countries (ECAB 0060 and ECAB 0063). Six lines showed good performance in three countries. These were ECAB 0020, ECAB 0019, ECAB 0023, ECAB 0081 and ECAB 0013. These results indicate that it was possible to identify new red mottled lines with better grain yield and resistance to the major diseases with broad adaptation. Lines with broader adaptation are preferred by seed producers because they justify seed production for a larger market.

In Rwanda, five red mottled varieties were selected in 2008 after evaluations in on-station and on-farm trials for the last four years (Table 56).

Table 54. Plant height, 100-seed mass and grain yield of red mottled bean lines selected at Awassa, southern Ethiopia.

Line	Plant height (cm)	100-seed mass	Grain yield (kg ha^{-1})
ECAB 0056	39	41.5	2555
ECAB 0034	39	42.6	2581
ECAB 0042	34	45.5	2991
ECAB 0008	36	51.6	3261
ECAB 0063	43	46.7	3163
ECAB 0060	33	42.7	2389
ECAB 0068	40	43.0	2576
ECAB 0041	38	41.8	2789
ECAB 0043	34	50.8	3121
ECAB 0047	39	44.7	2706
ECAB 0020	39	43.2	2574
ECAB 0098	34	41.6	2990
ECAB 0019	35	41.5	2981
ECAB 0023	38	45.8	2956
ECAB 0081	35	47.9	3173
ECAB 0013	37	43.7	2329
ECAB 0050	36	45.1	2783
ECAB 0027	42	49.1	3331
ECAB 0097	48	47.0	2780
ECAB 0082	40	42.5	2039
K132	36	43.8	2156
CAL 143	35	38.2	2398
GLP 2	45	40.6	2455
Lyamungu 85	37	49.7	2217
Local check	38	50.2	2018
Mean	37.6	44.8	2692

Table 55. Days to 50% flowering, maturity, seed mass and grain yield of advanced generation red mottled bean lines grown at two locations in Kenya.

Genotype	**Days to flowering**	**Days to maturity**	**100-seed mass (g)**	**Grain yield (kg ha^{-1})**		
				Kabete	Thika	Mean
ECAB 0007	43	84	45.5	2352	1884	2118
ECAB 0006	40	82	47.1	2415	1755	2085
ECAB 0042	41	81	41.5	2054	1974	2014
ECAB 0023	42	82	43.0	2015	1980	1998
ECAB 0038	41	83	51.4	1897	2014	1955
ECAB 0012	41	83	47.9	2199	1619	1909
ECAB 0010	42	83	46.3	2286	1456	1871
ECAB 0043	41	81	49.7	2011	1717	1864
ECAB 0033	40	81	56.8	2001	1719	1860
Checks						
GLP 2	43	84	47.5	1714	1303	1508
Goberasha	44	84	47.2	1752	1134	1443
K132	43	84	47.2	1834	1365	1600
KK 8	42	82	38.2	1446	1348	1397
Lyamungu 85	42	83	46.8	1745	1152	1448
Lyamungu 90	44	85	45.4	1522	1294	1408
Melke	43	83	47.4	1470	1045	1257
PVA 8	43	83	48.1	1560	1208	1384
SCAM 80CM/ 15	41	83	38.1	1623	1315	1469
Selian 94	41	83	32.5	1773	1390	1581
Simama	42	84	47.3	1830	1535	1683
Mean (Thika)	40.3	81	45.4	-	1372	1372
Mean (Kabete)	42.8	84	49.9	1927	-	1927
Trial Mean	41.5	83	47.6	1927	1372	1650
CV (%)	3.5	2.0				22.1
Locations (L)	**	**	**			**
Genotypes (G)	**	**	**			*
G x L	**	**	NS			NS
Error						

Table 56. Disease score and grain yield of four red mottled lines selected for multiple disease in Rwanda, 2008

Line*	BCMV	Ascochyta	Anthracnose	Angular leaf spot	Rust	Grain Yield (kg ha^{-1})
ECAB 026	2	2	1	3	2	3333
ECAB 001	2	3	1	5	2	2833
ECAB 019	2	3	1	6	2	3267
ECAB 0037	2	3	1	3	1	2333
ECAB 0019	3	4	1	3	1	1833

* ECAB 026, ECAB 001 and ECAB 019 were selected at Rubona and ECAB 0037 and ECAB 0019 at Rukira.
ECAB 0037 and ECAB 019 had resistant reaction to common bacterial blight at Rukira.
Source: Félicité Nsanzebara, 2008

Performance of Advanced lines from KP 86 and MCN nurseries. Twenty-one lines from KP86 population were distributed to bean programs in Uganda, Ethiopia, D. R. Congo, Tanzania and Kenya. Two lines KS 65-2 and KS 47-1 were selected in western D. R. Congo and pre-released (Kimani, 2006). In Kenya, five lines were recommended for full release after evaluation in national performance trials in December 2007 (Table 57). The results showed that the candidate varieties were more resistant to angular leaf spot, BCMV, halo blight and common bacterial blight compared to the susceptible checks. All candidate varieties, except KK22, were more tolerant to anthracnose compared with GLP 2. KK22 also was more susceptible to bean common mosaic necrotic virus (BCMNV) compared with other varieties and checks.

Table 57. Disease score and grain yield of five red mottled lines selected for multiple disease in Kenya and evaluated in national performance trials at nine sites for three seasons, 2008

Genotype	Market class	Angular* Leaf spot	Anth.	BCMNV	BCMV	Halo blight	CBB	Grain Yield (kg ha^{-1})
E8	Red mottled	2.3	1.4	1.1	2.2	1.5	2.2	1320
M22	Red mottled	2.1	1.6	1.0	2.4	1.7	2.4	1140
AFR 708	Red mottled	2.2	1.7	1.2	1.8	2.0	1.8	1050
KK8	Red mottled	2.3	1.6	1.1	1.9	1.7	2.0	1020
Lyamungu 85	Red mottled	2.3	1.4	1.2	2.6	1.8	1.8	1010
Checks								
GLP 2	Red mottled	2.4	1.9	1.1	2.2	2.1	2.2	1060
GLP 92	Pinto	2.8	1.7	1.2	2.8	1.6	2.9	800
LSD $_{0.05}$		0.41	0.54	0.75	0.76	0.32	0.68	260

Source: NPT Reports 2006-2007, KEPHIS; * Disease severity scores, anth= anthracnose.

Release of new varieties: Table 58 shows some of the bush red mottled varieties released in east and central Africa since 2003.

Contributors: Paul Kimani, Robin Buruchara (CIAT), Annet Namayanja (Uganda), Félicité Nzansebara, (Rwanda), Asrat Asfaw (Ethiopia) and Nkonko Mbikayi (D. R. Congo).

Collaborators: Bean Teams of Madagascar, Uganda, D. R. Congo, Rwanda, Ethiopia, Kenya and Tanzania

Table 58. Red mottled varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Countries of release
New Rosecoco	E8	2008	Kenya
Chelalang	Lyamungu 85	2008	Kenya
Kenya Umoja	AFR 708	2008	Kenya
Super Rosecoco	M22	2008	Kenya
CAL 98	CAL 98	2007	Madagascar
RWR 2355	RWR 2355	2007	Rwanda
RWR1180	RWR 1180	2007	Rwanda
Shyorongi	RWR 2245	2007	Rwanda
Ibado	AFR 722	2006	Ethiopia
RWR 2142	RWR 2142	2006	Rwanda
Lyamungu 90	Lyamungu 90	2005	DRC -West
NABE	AFR721	2003	Uganda

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2.3.3 Breeding red kidney bean varieties with multiple constraint resistance in eastern Africa

Rationale: Red kidney bean is one of the most important grain types grown by smallholders and consumed in rural and urban centres in East and Central Africa. An estimated 350,000 ha are grown annually in Africa (Wortmann et al., 1998). Red kidneys are highly marketable in many areas and have potential for export. They account for about 11% of beans marketed in this region. A market survey conducted in 2000 by the East and Central Africa Bean Research Network (ECABREN) showed that red kidney bean was important in Kenya, Tanzania, Burundi, Rwanda, Cameroon, southern Ethiopia, southern Sudan and Madagascar. However, these seed types are relatively low yielding under the low-input management. They are susceptible to biotic and abiotic stresses. Their productivity is severely constrained by angular leaf spot, anthracnose, root rots, bean stem maggot, low soil phosphorus and nitrogen, and drought. Production is dominated by a single variety, Canadian Wonder which was introduced in the region more than 50 years ago (CIAT, 2004). However the productivity of this variety has been on the decline because of susceptibility to diseases, especially angular leaf spot, anthracnose, common bacterial blight, root rots, drought and declining soil fertility. More recent releases such as Selian 97 have yet to meet consumer acceptability comparable to Canadian Wonder. Red kidney bean is predominantly produced by smallholder farmers, with limited options for inputs to reduce effects of biotic and abiotic stresses (CIAT, 2003). Because most of the resource poor smallholder farmers can hardly afford purchased inputs, breeding cultivars tolerant to the major stresses is considered as the most effective strategy for developing improved cultivars. A regional breeding program led by Selian Agricultural Research Institute (SARI) in Arusha, Tanzania and University of Nairobi, Kabete (Kenya) was started in 2001 to develop new high yielding red kidney cultivars with resistance to two or more biotic and abiotic stresses and with desirable grain characteristics for smallholder farmers in East and Central Africa (Kimani, 2005). Selection was carried out concurrently from existing and new populations at Arusha and Kabete. Promising lines with resistance to two or more or biotic and abiotic and improved yields were constituted into a regional nursery in 2003. The regional red kidney nursery was distributed to other national programs for participatory evaluation by farmers and researchers. This report highlights progress made in development of red kidney varieties fro smallholder farmers in eastern Africa between 2003 and 2008.

Materials and Methods: Red kidney program started with development of segregating populations from simple and multiple crosses, and introduction of red kidney grain type from CIAT, Colombia. During the first phase of this work, the segregating populations were selected for six to eight generations under natural and artificial disease epiphytotics, low soil fertility and drought stress. In second phase, red kidney lines with acceptable grain and resistance to major stresses were entered into regional evaluations to expose them to a wider range of pathogen diversity and production environments in East and Central Africa and to identify candidates for national and regional releases.

<u>Population development.</u> Germplasm from multiple constraint nurseries, segregating populations, advanced lines, regional disease nurseries and the regional program at Kabete (Kenya) and Selian Agricultural Research Institute, Arusha (Tanzania). Sources of resistance to anthracnose, angular leaf spot and root rots were identified and used in crosses with susceptible commercial cultivars.

At Selian, G 5686, BAT 332 and Mexico 54 were the used as sources of resistance to angular leaf spot, common bacterial blight, powdery mildew and rust based on local validation trials. UBR (92)25 was the source of resistance to low soil N, P and drought. G 22501, G22258 and G11746 were used as sources of resistance to bean stem maggot and drought. A total of 11 single, 21 three-way and 11 double cross populations were developed (Table 59).

At Kabete, breeding started with creation of segregating populations from bi-parent and multi-parent crosses. Parents were selected for known resistances to angular leaf spot, anthracnose, drought and tolerance to low soil fertility.

Selection for multiple stress resistance

<u>Selection at Selian.</u> Selection for priority stresses was performed from eight multiple constraint nurseries (MCN) constituted at Kabete in 2000, and also from segregating populations. MCN nurseries had 294 red kidney lines distributed as follows: MCN I (12 lines), MCN II (157 lines), MCN III (20 lines), MCN IV (47 lines), MCN V (12 lines), MCN VI (21 lines), Kabete PSP (18 lines) and KS-PSP (7 lines). These lines were evaluated for most important diseases in northern Tanzania which include angular leaf spot, common bacterial blight, anthracnose, rust, bean common mosaic virus and bean stem maggot at Selian and Olmotony field sites. Starting in 2001, a regional nursery of 100 red kidney advanced lines from the regional program at Kabete was evaluated for resistance to angular leaf spot, common bacterial blight, anthracnose, bean common mosaic virus and tolerance to manganese and iron toxicity at Selian.

Table 59. Populations generated at Selian Agricultural Research Institute, Tanzania to combine marketable grain characteristics of commercial cultivars with resistance to major biotic and abiotic stresses.

Single cross Populations	Three way cross populations	Double cross populations
CW* x G 11746	(CW x G 22258) x Mex 54	(CW x G22258) x (MASAI RED x Mex 54)
CW x G22258	(CW x G 22258) x G 5686	(CW x G 22258) x (MASAI RED x G 5686)
CW x G22501	(CW x G 22258) x BAT 332	(CW x G22258) x (MASAI RED x BAT 332)
CW x Mex 54	(CW x G 22258) x UBR (92) 25	(CW x G22258) x (MASAI RED x BAT 332)
CW x UBR (92)25	(CW x Mex 54) x UBR (92) 25	(CW X Mex 54) X (MASAI RED X UBR(92) 25)
CW x G 5686	(CW x Mex 54) x G 11746	(CW x MEXICO 54) x (MASAI RED x G 11746)
CW x BAT 332	(CW x Mex 54) x G 22501	(CW x G5686) x (MASAI RED x (UBR92) 25)
Selian 97 x G11746	(CW x G5686) x UBR(92) 25	(CW x G 5686) x (MASAI RED x BAT 332)
Selian 97 x G22258	(CW x G 5686) x BAT 332	(CW x G 11746) x (MASAI RED x G 5686)
Selian 97 x Mex 54	(CW x G 5686) x G 11746	(CW x G 11746) x (MASAI RED x BAT 332)
Selian 97 x G5686	(CW x G 5686) x G 22501	(CW x G 11746) x (MASAI RED x UBR (92) 25)
	(CW x G 5686) x G 22258	
	(CW x G 11746) x UBR (92) 25	
	(CW x G 11746) x BAT 332	
	(CW x G 11746) x Mex 54	
	(CW x G 11746) x G 5686	
	(SELIAN 97 x G 5686)x G 22258	
	(SELIAN 97 x G 5686) x G 22501	
	(SELIAN 97 x G 5686)x G 11746	
	(SELIAN 97 X G 5686) X BAT 332	
	(SELIAN 97 X G 5686) X UBR (92)25	

* CW= Canadian Wonder (syn GLP 24 in Kenya)

Selection at Kabete. More than 60 F_2 populations were initially grown Kabete Field station and selected for tolerance to diseases, seed type, type I or II growth habit over two generations. Selected plants were advanced in single plant progeny rows in F_3 and F_4 generations. F_4 bulks were screened for resistance to *Pythium* root rot, angular leaf spot and anthracnose using artificial inoculation at Kawanda Agricultural Research Institute (Uganda). They were concurrently tested for tolerance to low soil phosphorus in Kakamega and in a root rot infested field plot in Sabatia (Western Kenya). To select for yield potential, F_5 and F_6 lines were grown in preliminary and intermediate yield trials at four locations in Kenya. About 102 selected lines were evaluated in advanced yield trials at three locations. Two regionally important red kidney cultivars, Canadian Wonder and Selian 97, were included as checks. The 102 were constituted into a regional red kidney nursery which was distributed to collaborating countries interested in this grain type (CIAT, 2004).

Results and Discussion:

Selection for multiple resistance. More than 140 populations from single, three-way and double crosses were generated at Selian and Kabete. F_2 populations were screened for resistance to diseases at Kabete Field station and selected for seed type, type I or II growth habit over two generations. Selected plants were advanced in single plant progeny rows in F_3 and F_4 generations. Populations were managed as described for the red mottled class, including disease inoculations and evaluations. Red kidney lines found to combine tolerance to low soil P included NM 12806-2A-1, AND 1055-1, RWR 1742-1, NR 12634-6-1 and NR 12634-13C-1. AND 1055-1 was resistant to root rots in Kakamega and under artificial inoculation in Kawanda. Lines with combined tolerance to low P and low N included RWR 1742-1 and full sibs from the crosses NM 12806-2A and NR 12634-13C, NR 12638-1B, NR 12639-5 and NR 12634-9B-1, RWK 10, VTTT 920-26, NM 12806-2A and NR 12634-13C. Two lines showed high levels of tolerance to the three stresses. These were NM 12806-2A-1 and NR 12634-13C.

Selections were also made from KP86 populations. Canadian Wonder (GLP 24) was one of the parents from which these populations were derived (Table 60).

Table 60. F_4 and F_5 lines with multiple resistance selected from KP 86 populations inoculated with disease isolates at Kabete.

Cross/population	Number of lines	Combinations of resistance*
GLP 288 x M535	25	CBB, BCMV, angular leaf spot, bean stem maggot
L226-10 x NB 123	19	BCMV, rust, angular leaf spot, halo blight, bean stem maggot
M535 x L226-10	10	BCMV, halo blight, CBB
GLP 2 x NB 123	5	BCMV, rust, anthracnose and halo blight
GLP 2 x M535	3	BCMV, anthracnose, CBB, rust and angular leaf spot
GLP2 x GLP 288	6	Rust, angular leaf spot, BCMV, anthracnose, CBB, BSM
GLP 2 x L226-10	18	Rust, angular leaf spot, anthracnose, CBB
GLP 92 x NB 123	3	Rust, angular leaf spot, halo blight, BSM
GLP 288 x GLP 24	19	Rust, angular leaf spot, CBB and BCMV

* BCMV= bean common mosaic virus, CBB= common bacterial blight, BSM= bean stem maggot.
Source: CIAT, 2007

Evaluation of Advanced lines. At Selian, 43 lines selected from the MCN nurseries were subsequently distributed for further evaluation in Madagascar, Uganda and Rwanda (Table 61). In Tanzania, 23 lines with multiple resistance to diseases, low soil fertility and drought were selected from 294 MCN lines and evaluated in preliminary and advanced yield trials, uniformity cultivar trials (UCT) and finally the national bean yield trials (NBYT). However, selection from the segregating populations was delayed following of departure of the breeder for further studies.

Low yields were recorded in Madagascar. Yields of the best 12 lines varied from 710 to 1693 kg ha^{-1}. However, only five lines had better yields than Canadian Wonder (GLP 24) with a mean yield of 825 kg ha^{-1}. These were ECAB 0240 (889 kg ha^{-1}), ECAB 0247 (875 kg ha^{-1}), AND 931-B1 (982 kg ha^{-1}), TZ 201-439-3 (777 kg ha^{-1}), EMP 250-51 (1142 kg ha^{-1}), VTT 926/2-4 (1693 kg ha^{-1}) and UBR (91)45-1 (1266 kg ha^{-1}). ECAB 0240 and UBR (91)45-1 flowered in 40 days. TZ 201-439-3 was the last to reach 50% flowering (48 days).

Table 61. Red kidney lines selected at Selian and distributed to Uganda, Madagascar and Rwanda.

Source Nursery	Lines
MCN I	AND 932B –1, FEB 147-1, EMP 263A-1, RAA 28-1, TZ 201439-3, RWR 1742-1,RWR 1946-2, RWR 1873, RWR 1896-1
MCN II	NR 1263–7-1, NR 12634 –2A-1, NR 12634 –6A-1, NR 12634-9B-1, NR12634 –11B-1, NR12634 -11C, NR 12634 –12B –1, NR 12635 –2B –2, NR 12638 –2 -1, NM 12531 –9 –1, NM 12657 – 10B –1, NR 12672 – 5 –1, EMP250 –5-1
MCN III	LRK 32, AND 1064-1, AND 1063-1, FEB 195-1, POA 8-1, RAA 31-2 AND OBA 3-1
MCN IV	VTT 920/26, VTT 921/11, VTT 921/11-1, VTT 926/2-4 and VTT 926/12-2
MCN IV	UBR (91) 15 –1, UBR (92)17-2 and UBR (91)45-1
Kabete PSP	K13/4A –C – 1 and K13/41 AF 12-12
KS PSP	KS 7 –1, KS 45-1, KS 45-3-2 and KS 56-1

In contrast, relatively high yields were recorded in Ethiopia. Grain yield varied from 2300 kg ha^{-1} (ECAB 0281) to 3452 kg ha^{-1} (ECAB 0270). However, 21 lines (including Canadian Wonder) yielded better than Selian 97. In Kenya, the best yielding lines were (in decreasing order) ECAB 0296 , ECAB 0224 , ECAB 0240, ECAB 0234, ECAB 0219, ECAB 0246, ECAB 0228, ECAB 0290, ECAB 0262, ECAB 0288, ECAB 0251, ECAB 0231, ECAB 0232, ECAB 0248, ECAB 0282, and ECAB 0292. Mean yields at Kabete and Thika varied from 1908 kg ha^{-1} for ECAB 0292, to 2218 kg ha^{-1}for ECAB 0296. Mean yields were 1322 kg ha^{-1}for Canadian Wonder and 1326 kg ha^{-1} for Selian 97. Twenty-one lines selected at Awassa (Ethiopia) were also selected in previous trials in Kenya. Among the lines selected in four countries were: ECAB 0201, ECAB 0252, ECAB 0240, ECAB 0267 and ECAB 0247. Thirteen lines performed well and were selected in three countries. Only four lines were selected in two countries (ECAB 0295 and ECAB 0224).

Variety Release. Three red kidney (M18, L36 and L41) were among the 16 candidate varieties validated in national performance trials conducted over three seasons in 2005 and 2006 at nine locations in Kenya. Table 62 shows some characteristics of these lines.

Table 62. Mean performance of red kidney lines in the national performance trials conducted at nine sites for three seasons in Kenya.

Genotype	**Market class**	**Angular* Leaf spot**	**Anth.**	**BCMNV**	**BCMV**	**Halo blight**	**CBB**	**Grain Yield (kg ha^{-1})**
L41	Red kidney	2.1	1.6	1.1	2.7	1.9	2.2	1130
M18	Red kidney	2.0	1.4	1.0	2.7	1.7	2.0	1090
L36	Red kidney	2.3	1.6	1.0	2.4	1.7	2.2	1050
Checks								
GLP 2	Red mottled	2.4	1.9	1.1	2.2	2.1	2.2	1060
GLP 92	Pinto	2.8	1.7	1.2	2.8	1.6	2.9	800
$LSD_{0.05}$		0.41	0.54	0.75	0.76	0.32	0.68	260

Source: NPT Report 2006, KEPHIS; * Disease severity scores, anth= anthracnose, BCMNV= bean common mosaic necrotic virus, BCMV=bean common mosaic virus, CBB= common bacterial blight.

Several lines of red kidney have been released in eastern Africa. Table 63 shows some of released lines between 2003 and 2008. NABE 13 (RWR 1946) is high yielding and is resistant to bean root rots, angular leaf spot, anthracnose and is adapted to low soil fertility. NABE 14 (RWR 2075) is a high yielding variety with multiple resistances to low fertility acid soils, root rot, anthracnose and angular leaf spot.

Table 63. Red kidney and large red bush varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Country of release
Kenya Red Kidney	M18	2008	Kenya
Kabete Super	L36	2008	Kenya
Kenya Wonder	L41	2008	Kenya
Nitu	G16157	2005	D. R. Congo
DRK 64	DRK 64	2008(pre-release)	Madagascar
UBR (91)45-1	UBR (91)45-1	2008 (pre-release)	Madagascar
ODR	ODR	2008 (pre-release)	Madagascar
RWR 2091	RWR 2091	2006	Rwanda
Selian 06	Flor de Mayo	2008	Tanzania
NABE 14	RWR 2075	2006	Uganda
NABE 13	RWR 1946	2006	Uganda
ACOS Red	-	2007	Ethiopia

Source: National Bean program reports, 2006-2008.

Contributors: Paul Kimani, Sostenes Kweka (Tanzania), Annet Namayanja (Uganda), Hery (Madagascar), Lodi Lama (D. R. Congo) and Robin Buruchara (CIAT)

Collaborators: Asrat Asfaw, Bean Teams at Selian, Kabete, Namulonge, Kawanda, Antananarivo, Awassa, Rubona and Melkassa.

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2.3.4 Development and release of new Speckled Sugar bean varieties with multiple disease resistance in eastern Africa

Rationale: Speckled sugars belong to the cream colored market class, which accounts for 10% of Africa's annual production. They are produced on 240,000 ha annually in eastern and central Africa, and on 120,000 ha in southern Africa. Wortmann et al (1998) reported that speckled sugars are of high to moderate importance in Kenya, South Africa, Angola, Uganda, Zambia, Zimbabwe, Lesotho and eastern Congo. Speckled sugars are high in demand in South Africa and Zimbabwe. South Africa imports speckled sugars from China and other countries to meet its domestic requirements. Southern Africa countries are therefore a potential market for ECABREN countries. In the Great lakes region, sugar bean is grown in eastern D. R. Congo for export to urban centers in the western part of the country. Brown and speckled sugars are also important for domestic markets in Ethiopia, Uganda, Tanzania and Rwanda. Speckled sugars are exported to regional markets by D. R. Congo and to international markets by Madagascar. However, productivity of speckled sugars is constrained by rust, angular leaf spot, common bacterial blight, halo blight and poor tolerance to low soil nitrogen and phosphorus. Varieties with multiple resistance to diseases is probably the most effective and efficient strategy for managing these diseases, especially in low input systems common in eastern Africa. The East and Central Africa Bean Research Network (ECABREN) in collaboration with Southern Africa Bean Research (SABRN) network started a collaborative program to develop high yielding speckled sugar varieties with resistance to two or more biotic and abiotic constraints and marketable grain characteristics. The national bean program of D. R. Congo (INERA) has been leading a regional initiative to develop and disseminate improved varieties of speckled sugars for the last eight years, with a back-up regional program in Kenya, focusing on smallholder production. Objective of the program is to develop speckled sugar cultivars with improved grain yield and resistance to angular leaf spot, common bacterial blight, rust and tolerance to low soil fertility (Kimani, 2005). Selection activities were conducted collaboratively in Kenya and D. R. Congo countries with promising candidate lines constituting a regional nursery for evaluation by interested member countries. This report highlights progress made in this program since its inception.

Materials and Methods: A regional germplasm collection was assembled at Kabete and screened for sugar grain type. The collection comprised of segregating populations (KP01) derived from 52 parents of diverse genetic backgrounds and known resistance to specific stress factors, especially angular leaf spot, common bacterial blight and halo blight. Included in this collection were six multiple constraint nurseries (MCN) constituted from advanced lines developed at CIAT, Colombia and from regional breeding programs in East and Central Africa. The materials were initially screened for adaptation and tolerance to biotic stress factors at Kabete Field Station, University of Nairobi and at INERA- Mulungu Research Station in D. R. Congo. At Mulungu, lines selected from F_2 and F_3 populations were evaluated in participatory trial sites in eastern D. R. Congo (Mbikayi and Kimani, 2004). In Kenya, single plant selections were selected from KP01 population and used to establish F_3 and F_4 progeny rows at Kabete Field Station. Progeny rows were selected on basis of reaction to angular leaf spot, rust, root rot, common bacterial blight and plant characteristics. F_5 lines were grown in preliminary yield trials. F_6 lines were grown in intermediate yield trials at three locations. Twenty-seven selected lines were finally selected for advanced regional yield trials in Uganda, D. R. Congo and Kenya. 'Brown Speckled' released in Ethiopia and Sugar 73 (Uganda) were included as checks. Disease scoring followed the standard CIAT scale (Schoonhoven and Pastor-Corrales, 1987).

In Kenya, progeny from KP 86 F_2 populations were selected for eight generations for resistance to six diseases (rust, angular leaf spot, anthracnose, halo blight, BCMV and common bacterial blight), yield and seed characteristics both in the greenhouse and in the field. Disease assessment was based on artificial inoculations and natural epiphytotics in the field. Disease assessment was done 21 days after inoculation (R6) and also at mid-pod filling (R8). Susceptible plants were discarded. To determine the yield potential of early generation lines, more than 200 F_4 and F_5 lines were evaluated at five locations for two seasons. Fifty-one lines were selected and evaluated in advanced yield trials at 10 locations for three seasons and also distributed to countries interested in this grain type (Tanzania, Uganda, D. R. Congo and Kenya). Four commercial varieties (GLP2, GLP 24, GLP 92 and GLP 1004) were included as checks. Twenty-one lines were selected for participatory on-farm evaluation in eight districts for two seasons. Yield data for 51 lines and the four check cultivars in 24 environments were analyzed for type 1 and type 4 stability parameters (Francis and Kannenberg, 1978; Lin et al 1986; Lin and Binns, 1988, 1991). Finally, nine lines were selected for multi-location national performance trials conducted at nine sites for three seasons.

Results and Discussion: Performance of F_8 lines selected from the KP01 populations in Kenya is shown in Table 64. Results showed that there were significant genotypic differences for duration to flowering, maturity, pod m^{-2}, 100-seed mass and grain yield (Table 64). Environmental effects were significant for phenology, angular leaf spot, anthracnose, rust, root rot, 100- seed mass and grain yield (P>0.01). Significant genotype x environment interaction was detected for days to flowering, root rot, days to maturity, 100-seed mass and grain yield. Angular leaf spot incidence was higher at Thika. Anthracnose incidence was highest at Juja. Rust incidence was highest at Juja during short rain season. Root rot was most severe at Thika. ECAB 0811 and ECAB 0822 showed intermediate reactions to root rot at this site. All other lines were rated resistant. The results indicated that some of the new lines had considerable yield advantage compared to the check cultivars. The results showed that 21 new lines produced higher grain yield compared to 'Brown Speckled' (Table 64). Seven lines produced higher grain yield than Sugar 73. These results were subsequently confirmed in advanced yield trials. Ten lines showed better yield that Sugar 73 and Brown Speckled. These were ECAB 0806, ECAB 0822, ECAB 0810, ECAB0807, ECAB 0805, ECAB 0808, ECAB 0817, ECAB 0826 and ECAB 0802. Mean yield of test lines over two environments varied from 1484 to 1675 kg ha^{-1} compared with 1455 kg ha^{-1} for Sugar 73 and 1411 kg ha^{-1} for Speckled Sugar. The test lines showed resistant reactions to angular leaf spot, anthracnose, rust and root rots in two environments.

Results from INERA-Mulungu are presented in Table 65. Seven sugar lines were selected from 40 test lines. Five of the selected lines flowered and matured earlier than M'Mafutala, the check variety. Five lines showed higher 100-seed mass and grain yield than the check. These lines showed either resistant or intermediate reactions to angular leaf spot, anthracnose, ascochyta blight and rust at Mulungu. Two lines had more than 500 kg ha^{-1} yield advantage over the check.

Advanced yield trials were conducted at INERA-Mulungu for the 27 lines received from the regional speckled sugar nursery in Kenya. These were separated into bush growth habit (Type I and II) and climbers (Type III and IV). Results showed that lines with bush growth habit (Types I and II) flowered in 39 to 48 days, and matured in 82 to 94 days. As expected, climbing bean lines flowered and matured later. There was high disease pressure due to angular leaf spot at Mulungu. However, all selected lines had intermediate reactions to angular leafspot. Most of the lines showed resistant scores to anthracnose, aschochyta and rust. Grain yield varied from 1009 kg ha^{-1} for RWV 1128-2 to 2004 kg ha^{-1} for KS 151-3F11-1, and 2024 kg ha^{-1} for P94056. The climbing sugar bean lines did not show the expected superiority for grain yield compared to the bush lines. Ten bush lines and three climbers were selected for further evaluation. The selected bush lines were P94056, KS 65-2, NM 12652/9A-1, NM 12650/4A-1, NM 12633/9A, VTTT 926/3-5, NM 12656/14-1, MX 875-3T, NM 12647/A-1 and KS 151-3F11-1. The selected climbers were MAC 70-2, RWV 1134 and RWV1128-2.

In Western Congo, two lines KS 65-2 and KS 47-1 which performed well in lowland conditions were recommended for pre-release. In Uganda, MAC 31 was selected. This line became very popular in local markets because of its large seeds and pods. It is now widely grown in eastern Uganda (Mbale district) for domestic and export markets.

Table 64. Mean duration to flowering, maturity, pods m^{-2}, 100-seed mass and grain yield of F_8 speckled sugar bean lines selected from KP01 populations and grown at four environments in Kenya.

Genotype	Days to 50% flower (d)	Days to maturity (d)	Pod m^{-2}	100-seed mass (g)	Grain yield (kg ha^{-1})				
					Kabete	Thika	Juja (SR)	Juja (LR)	Mean
ECAB0811	42.8	82.1	174.8	50.7	2263	1862	2105	2185	2104
ECAB0807	40.6	81.1	170.0	45.6	1567	1768	1986	2079	1850
ECAB0801	42.2	83.5	188.9	37.1	1684	1784	1858	1925	1813
ECAB0822	43.0	82.5	146.3	41.7	1955	1238	1910	2067	1793
ECAB0813	42.4	83.0	192.4	45.8	1678	1179	2167	2059	1771
ECAB0815	39.7	80.6	150.9	45.7	1437	1686	1598	2208	1732
ECAB0823	39.4	80.3	170.7	42.0	1373	898	2231	2297	1700
SUGAR 73	42.8	82.9	197.8	52.3	1597	1675	1276	2115	1666
ECAB0810	43.3	83.3	179.1	46.8	1149	1602	1684	2212	1662
ECAB0808	40.4	80.9	168.2	42.3	1756	1500	2001	1386	1661
ECAB0827	43.2	82.8	154.8	39.8	1889	1071	1579	1930	1617
ECAB0809	43.0	82.2	185.3	47.1	900	1755	1812	1899	1592
ECAB0821	38.2	80.3	120.4	44.3	1373	1373	1757	1857	1590
ECAB0802	41.7	82.2	179.8	45.8	1356	1711	1399	1846	1578
ECAB0805	40.5	81.3	201.5	42.6	1040	1463	1617	2093	1553
ECAB0806	42.9	83.2	186.5	44.0	1785	1566	876	1538	1441
ECAB0817	40.2	80.8	156.9	43.8	1390	1126	1574	1496	1397
ECAB0814	39.5	81.0	147.2	44.4	1449	1314	1879	762	1351
ECAB0804	43.1	82.7	197.2	37.8	1026	1810	1260	1226	1331
ECAB0826	40.2	81.4	163.7	43.1	1364	807	1257	1879	1327
ECAB0818	40.9	81.9	154.3	40.6	806	1859	1135	1252	1263
ECAB0824	41.3	81.1	168.1	41.5	684	1592	1775	809	1215
Brown Speckled	41.8	81.9	171.1	34.7	831	926	1578	1421	1189
Mean	41.5	81.0	165.9	43.0	1330	1413	1521	1602	1476
CV(%)	3.9	2.1	25.1	4.5					21.0
Genotypes (G)	**	**	**	**					**
Environments (E)	**	**	**	**					**
G x E	**	**	NS	**					**

*, **: Significant at 5 and 1 % probability levels, respectively; NS= not significant; SR= short rain and LR=long rain seasons.

Table 65. Days to 50% flowering, maturity, and seed mass and grain yield of sugar grain type bean lines selected, Mulungu, D. R. Congo.

Genotype	Days to flowering	Days to maturity	100-seed mass (g)	Grain yield (kg ha^{-1})
P94056	42	92	27.5	2024
KS 65-2	48	92	34.8	1858
MCD 2519-1	41	85	33.5	1707
NM 12652/9A-1	41	85	16.0	1418
NM 12633/9A	39	82	44.2	1411
VTTT 926/3-5	41	88	40.2	1327
NM 12656/14-1	39	82	42.5	1246
M'Mafutala (Check)	48	92	23.1	1216
Trial Mean				1191
LSD (0.05)				495
CV (%)				23.7

Participatory Variety Selection. A total of 113 on-farm trials were conducted in Kenya; 47 in the long rain season and 66 during the short rain season. Sixty-six farmers were interviewed during the post-trial evaluation. Most farmers had grown the test lines for the two seasons. Over 95% of the participating farmers were women. Except for Nakuru, Embu and Kisii, farmers in other districts grew the lines in pure stands. In Nyeri, farmers selected line E2 because of high yield, taste, thick soup and fast cooking. In Taita-Taveta, farmers selected E7 based on grain color, yield, earliness, seed and pod size, disease resistance and tolerance to heavy rain. In Embu, farmers selected E4 and E7. Primary selection criteria included maturity, yield, seed traits, taste, reaction to diseases and pests, and tolerance to excess rain. Farmers in Kisii, Kakamega and Machakos listed similar criteria.

Stability analysis. Plotting the grand mean yield against the coefficient of variation (CV%) divided the genotypes into four groups: Group I had high yield, small variation; Group II had high yield, large variation, Group III had low yield, small variation, and Group IV had low yield and large variation. E7 showed the showed the smallest variation across environments. GLP 585, a commercial check had the lowest grain yield and the largest CV across environments. Analyses based on type 1 stability parameter showed that E2 and E7 combined high yield and stability. These two lines were rated better than the commercial checks. E2 was rated as high yielding and stable by type 4 stability analyses.

National performance trials and release. Based on farmer assessments and on-station evaluation, four sugar lines were registered for the nation performance trials (NPT). This trial with 16 bush entries lines and three checks was conducted at nine sites. The national trials were conducted over two long rain (March-August) and short rain seasons (November –December). The check varieties were GLP x 92 ('Mwitemania'), GLP 2 (Rosecoco) and GLP 1127 ('New Mwezi Moja'). Table 66 shows the performance of sugar lines in these evaluations.

Table 66. Mean performance of speckled sugar genotypes in the national performance trials conducted at nine sites for three seasons in Kenya.

Genotype	Angular Leaf spot*	Anth.	BCMNV	BCMV	Halo blight	CBB	Grain Yield (kg ha^{-1})
E2	2.3	1.5	1.0	2.0	1.8	2.2	1200
E4	2.2	1.5	1.0	2.6	2.0	2.6	1070
E7	2.5	1.4	1.1	2.5	1.7	2.4	1080
Checks							
GLP 92	2.4	1.7	1.1	2.8	2.2	2.9	800
GLP 2	2.8	1.9	1.3	2.2	2.9	2.2	1060

Source: NPT Reports 2006 and 2007, KEPHIS ; * Disease severity scores.

The results showed that E2 had 17.7% yield advantage over the best check and 24.8 % over the mean of the checks. E4 had a 4.2% yield advantage over the best check across the nine environments and 11.1% over the mean of the checks. E7 showed a 5.1% yield advantage over the best check and 12.1% over the mean of the checks. Disease severity rating showed that the test lines had favorable reactions to several diseases, and showed lower levels of susceptibility compared with the check varieties. For example GLP 92 had 6.63% incidence for angular leaf spot compared to 4.4% for E2, 4.6% for E4 and 5.3% for E7. For anthracnose, GLP 2 had a 3.5% incidence compared with 1.9% for E2, 1% for E7 and 1.9% for E4. BCMV incidence was 23.8% for GLP 92 compared with 12.5% for E2, 18.9% for E7 and 19% for E4. Incidence of common bacterial blight was 17.4% for GLP 92 compared with 9.7% for E2, 9.8% for E7 and 7.6% for E4. Mean incidence for halo blight was 3.6% for GLP 2, compared with 2.7 % for E2, 3.2 for E7 and 1.5% for E4. The three sugar lines (E2, E4 and E7) were recommended for full release the National Variety Release Committee.

Variety Release and Conclusions: Several new speckled sugar varieties were released in eastern Africa between 2003 and 2008 (Table 67). In Uganda, Sugar 73 was released as NABE 5. MAC 31, a climber was released as NABE 12. In Ethiopia, 'Kranskop', which originated from South Africa was released. In Kenya, three bush and one climbing bean speckled sugar varieties were formally released in 2008. These results indicate that improved sugar bean varieties were identified from the working collection and locally developed populations. However, color retention in sugars remains a challenge. Most sugar varieties change from preferred wine red speckles on cream or white background to brown after storage, thus losing their consumer appeal.

Table 67. Speckled sugar bush and climbing bean varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Country of release
Miezi Mbili	E2	2008	Kenya
Kenya Early	E4	2008	Kenya
Kenya Sugar bean	E7	2008	Kenya
Kenya Safi	MAC 13	2008	Kenya
NABE 5	Sugar 73	2006	Uganda
NABE 12	MAC 13	2007	Uganda
Kranskop	Kranskop	2007	Ethiopia
KS 65-2	KS 65-2	2006 (pre-release)	D. R. Congo (west)

Source: National program reports, 2006-2008

Contributor: Paul Kimani (CIAT) and Agnes Mwangombe (Kenya).

Collaborators: Nkonko Mbikayi (D. R. Congo), Annet Namayanja (Uganda), Teshale Assefa (Ethiopia)

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2.3.5 Breeding small and medium red bean varieties resistant to multiple stresses for smallholder producers in eastern Africa

Rationale: Small and medium red bean cultivars are the second most important grain type grown by smallholder farmers in East and central Africa after the red mottled class. They account for more than 20% of bean grown and marketed in East, Central and Southern Africa. An estimated 670,000 ha are sown with small red bean each year. They are widely grown by smallholder farmers and consumed in rural and urban centres in the region. Small reds are of high to moderate importance in Ethiopia, Rwanda, Burundi, Kenya, Madagascar, D. R. Congo, Uganda and Tanzania (Wortmann et al., 1998). Although they are generally moderate to high yielding, their productivity is severely constrained by rust, angular leaf spot, root rots, low soil P and N. For example, a recently released and widely adopted climber 'Umubano' succumbed to *Fusarium* wilt in Rwanda and bean common mosaic virus in Kenya. Many farmers have stopped growing this variety despite its good yield potential. Red Wolaita, probably the most important variety in Ethiopia for domestic market, is susceptible to rust, angular leaf spot, anthracnose and common bacterial blight. GLP 585, released in 1984, is probably the most popular small red cultivar in Kenya. It is however very susceptible to rust, anthracnose, root rots and angular leaf spot. Masaai Red is a popular landrace in Tanzania but susceptible to rust and other diseases. A regional program led by Ethiopian national program in partnership with University of Nairobi, Selian Agricultural Research Institute at Arusha, Tanzania and CIAT was initiated in 2001 to develop high yielding, marketable small red bush bean cultivars with tolerance and/or resistance to a combination of three or more biotic and abiotic stresses and suitable for production in sole and intercrop systems in Africa. Our specific objectives were to: i) initiate crossing programs to develop new populations segregating for priority traits at Awassa, Selian and Kabete, ii) identify recombinants from the populations, iii) evaluate promising lines for resistance to biotic and abiotic stresses, iv) constitute a small and medium red bean nursery for regional evaluation, and v) conduct multi-location and participatory evaluations with farmers and release candidate varieties.

Materials and Methods: A regional breeding nursery for small and medium red was constituted from advanced lines from CIAT and national programs of Kenya and Ethiopia in 1998/1999 (CIAT, 2002). Multi-parent crosses were used to create segregating populations. Parents included in the crossing block were selected based on known resistance to angular leaf spot, anthracnose, rust and tolerance to low soil fertility. Selected commercial varieties and donor parents for specific traits were used in crossing programs in Kenya, Ethiopia and Tanzania to combine resistances to biotic and abiotic stresses with farmer preferred traits in single, three way and double crosses. The segregating populations were grown at Kabete Field Station, (Kenya) and at the Southern Agricultural Research Institute (SARI) in Awassa (Ethiopia) and selected for tolerance to diseases, plant and grain type for three generations. F_4 and F_5 bulks were screened for tolerance to root rots and tolerance to low soil fertility in Kakamega and Mulungu Station in Eastern Congo. Lines selected from segregating populations for disease resistance and other agronomic traits were evaluated in preliminary, intermediate and advanced trials in Ethiopia, Kenya, Tanzania, Uganda, Madagascar and Rwanda. Twenty-five advanced generation small red lines were evaluated at eight locations in Kenya, three in Cameroon, two in Ethiopia (Awassa and Melkassa), and one each in Madagascar and Tanzania (CIAT, 2003). The trials were laid out in a 6 x 6 lattice design with three replicates. Each entry was sown in four, 5 m rows. Regionally important commercial cultivars were included as checks. These were: Red Wolaita from Ethiopia, Maasai Red from Tanzania and GLP 585 (Wairimu) from Kenya. The entries were also included in participatory variety selection trials at two sites in Uganda, three in Rwanda and two in Kenya.

Results and Discussion:

Population development. In Kenya, crosses were made to transfer rust, anthracnose, root rots and angular leaf spot resistance to GLP 585 (locally known as 'Red Haricot') and Maasai Red. Roba-1 and Awash were used as sources of rust resistance in these crosses. G2333 and Vunikingi contributed resistance to root rots and anthracnose. Mexico 54 and G5686 were donors for angular leaf spot resistance genes. Four hundred twenty successful pollinations were made for the GLP 585 improvement program and 469 pollinations for Maasai Red program.

The Ethiopian crossing program for small reds was started in 2001 at Awassa Regional Research Centre. It focused on improvement of Red Wolaita, the most popular and widely grown small red in Ethiopia. Red Wolaita is low yielding and susceptible to rust angular leaf spot (ALS), common bacterial blight (CBB), anthracnose, drought and bean stem maggot (BSM). It is widely adapted and has attractive and marketable seed color. Donor parents used in the crossing program included G6, EMP 376, G6450, DOR 794, DOR 716, EMP 375 and EMP 252. Additional donor parents selected for the expanded program included Mexico 54 (ALS), G5686 (ALS), XAN lines (CBB), G2333 (anthracnose), Beshbesh and Melka (BSM), Awash-1 and Roba (rust). In addition to simple crosses, the crossing program developed multi-parent males with multiple resistances for backcrossing to the recurrent parents (Red Haricot, Maasai Red and Red Wolaita). Several populations were developed at Awassa in 2005 and 2006 (Table 68). These populations were advanced through single pod bulk and modified pedigree methods and also used for genetic studies (Asrat, 2006). Selection criteria include resistance to angular leaf spot, common bacterial blight, floury leaf spot, rust and drought.

Table 68. Populations developed at Southern Agricultural Research Institute, Awassa, 2005-2008.

Code	**Pedigree**	**Remarks**
SN 1	Red WolaIta x Vax-6	Small seeded progeny
SN 2	SNNPR-1-20 (MA4 x Mex-235)	Small seeded progeny
SN 3	RAB-589 x SNNPR-1-42	Small seeded progeny
SN 4	ETAW-01-L-5-19A x ETAW-01-L-3-12A	Medium white progeny
SN 5	AFR-702 x Mex-54	Large seeded progeny
BSE-03-01	CIFAC-87100 / CIM9314-36 // HAL-5 / MEX-54	Large seeded progeny
BSE-03-03	RWR-719 /// G1175-3/ Red Wolaita // RAB-585 / Mex-54	Small seeded progeny
AWB-0401	Red Wolaita///RAB-585/DOR-716//RWR-719/RAZ-54	>70 F_2 plants selected
AWB-0402	Red Wolaita ///MUC-95/EMP-212//RAB-585/Mex-54	>80 F_2 plants selected

At Selian, 6 F_2 populations were generated from single crosses of Maasai Red with Mex 54 (angular leaf spot), BAT 332 (angular leaf spot), UBR (92)25 (low soil N), G5686 (angular leaf spot), G11746 and G22258 (bean stem maggot). Fourteen three-way and 11 double crosses were subsequently made with the same set of parents to generate combinations of resistance to angular leaf spot, bean stem maggot and adaptation to low soil fertility and small red grain type. Due to departure of the breeder for further studies, limited selection was conducted on these populations.

Early generation selection. Five populations developed at Awassa were evaluated for different constraints including moisture stress. Five $F_{1.2}$ populations were first evaluated at Awassa under early and late sown conditions during the main season (meher). The best performing $F_{1.2}$'s were advanced to F_3. 169 $F_{1.3}$ seeds of each family were divided into three equal parts and evaluated for stresses prevalent at each of the three contrasting test sites during the short rain season (belg); Awassa (1750 m) for common bacterial blight, Kokate (2161m) for tolerance to low soil P and N, and at Amaro (1426 m) for drought. Five checks Omo-95(RWR-719), DOR-554, DICTA-105, Roba and Red Wolaita were included in the trial. The best populations were selected and advanced to F_4 using single pod bulk method. Seventy-one $F_{1.3}$ families combining high yield with biotic and abiotic stress resistance/tolerance under natural conditions were selected and advanced to F_4. The moisture stress was very severe during the cropping season at Amaro and even cowpea which is drought tolerant totally failed at Amaro in this season. A majority of the families did not yield at all, but 12 families gave grain yield of more than 1000 kg ha^{-1} (Table 69). CAW-02-03-10-7, CAW-02-04-7-7 and CAW-02-01-2-1 gave the best yields of 1549, 1520 and 1442 kg ha^{-1} under moisture stress, compared with yields of DOR-554 and Omo-95 that gave 678 and 661 kg ha^{-1}, respectively. These families also expressed good yielding potential and resistance to diseases both Awassa and Kokate test locations (Tables 69 and 70).

The 71 $F_{1.4}$ families from five populations were further evaluated for two generations ($F_{1.4}$ and $F_{1.5}$) under drought stress at Amaro during the meher and belg seasons following population bulk method. From best performing families, five most vigorous plants were selected to create progeny rows for line selection. This resulted in 265 $F_{1.6}$ lines. These lines were evaluated in a preliminary yield trial at Awassa during the meher season. The trial was laid in augmented randomized block design. Three checks (Omo-95, Red Wolaita and DOR-554) were included. The lines were planted in single, 2m row plots spaced at 80cm. The test lines expressed variability for grain yield. Grain yield of the 2 m row plots varied from 251 g for (CAW-02-04-7-7-2) to 967g for (CAW-02-03-8-1-1). Fifty-one lines out-yielded the best check variety. Two populations (RWR-719///Red Wolaita/ICTA JU-95-4//XAN-317/DOR-794 and ROBA///EMP-445/DFA-64//Red Wolaita/RAB-589) accounted for more than 92 % of the best yielding lines. The best performing 95 lines were advanced to F_7 and planted in advanced yield trials at six locations during the meher season. Results showed that lines developed from drought tolerant families expressed good performance in favorable environments.

Advanced Yield Trials. In Kenya, 10 advanced lines were selected from the preliminary and intermediate yield trials at Kabete, Juja and Thika (Tables 71 and 72). These had a yield potential above 2 t ha^{-1} and matured in less than 95 days. CAL 170B-4, DFA 52-1, DFA 57, EMP250-3-1, FEB 200-1, ECAB 0408, ECAB 0416, ECAB 0424, ECAB 0428, ECAB 0426 and ECAB 0411 were susceptible to rust (score of 7 and above) at Thika (CIAT, 2001). BRB 71-1 and TLP 8-1 were discarded due to susceptibility to black root. FEB 200-1 showed moderate tolerance to low soil P at Kakamega. All lines showed intermediate or resistant reactions to rust, angular leaf spot and anthracnose at the three sites.

Table 69. Grain yield (kg ha^{-1}) of 12 $F_{1.3}$ and $F_{1.2}$ families at three locations in southern Ethiopia.

Families	Pedigree	$F_{1.3}$ (Belg season)				$F_{1.2}$ (Meher)	
		Awassa (1750m)	Kokate (2161m)	Amaro (1426m)	Mean	Awassa (E)	Awassa (L)
CAW-02-01-1-1	Red Wolaita /// [DOR-716 / ICTAJU95-2//G-6 / DICTA-106]	1796.6	2187.5	1259.1	1747.8	5615.0	3118.8
CAW-02-01-1-2		2271.3	2265.6	1307.2	1948.0	4207.5	3958.8
CAW-02-01-2-1		2064.4	1875.0	1441.9	1793.8	5566.3	2002.5
CAW-02-01-5-1		1591.9	1484.4	1032.2	1369.5	5737.5	2382.5
CAW-02-02-5-1	Red Wolaita /// XAN-314 / EMP-375//MOC106 / DOR-548]	1552.8	1328.1	1408.4	1429.8	3966.3	3107.5
CAW-02-02-6-3		3272.2	1562.5	1198.8	2011.2	3536.3	2108.8
CAW-02-03-10-6	RWR-719 ///Red Wolaita / ICTAJU 95-4 // XAN-317 / DOR-794	2437.5	2656.3	1243.8	2112.5	3982.5	2138.8
CAW-02-03-10-7		2529.4	1875.0	1549.1	1984.5	4282.5	3565.0
CAW-02-03-15-4		2136.9	2500.0	1355.3	1997.4	4120.0	3032.5
CAW-02-04-8-3	Roba / EMP-445 / DFA-64 //Red Wolaita / RAB-589	1577.5	1250.0	1355.3	1333.7	4500.0	3398.8
CAW-02-04-7-7		2137.2	2109.4	1520.3	1922.3	4100.0	2413.8
CAW-02-04-3-5		1251.3	1250.0	1215.3	1238.9	4828.8	2855.0
Red Wolaita **		1749.7	1953.1	317.8	1340.2	3986.1	-
Omo-95(RWR-719)**		1431.6	2031.3	660.9	1374.6	3644.1	-
Roba-1**		1555.9	1679.7	68.8	1101.5	-	-
DOR-554**		2169.1	1835.9	678.4	1561.2	-	-
DICTA-105**		1780.9	1796.9	211.6	1263.1	-	-
Highest yield obtained		3681.6	3671.9	1549.1	2300.4	-	-

E = early sown , L = late sown, ** Checks

Table 70. Disease, pod borer resistance scores, days to flowering and maturity of 12 $F_{1.2}$ and $F_{1.3}$ families at three locations in southern Ethiopia.

Families	$F_{1.3}$				$F_{1.2}$											
	Awassa (Belg)				Awassa (Meher early sowing)						Awassa (Meher late sowing)					
	ALS*	CBB	HB	Pod borer	ALS	CBB	Rust	FLS	DF	DM	ALS	CBB	Rust	FLS	DF	DM
CAW-02-01-1-1	1	6	1	3	1	5	1	2	52	102	1	5	1	2	47	96
CAW-02-01-1-2	1	6	1	3	1	6	1	1	52	104	1	6	1	1	50	95
CAW-02-01-2-1	1	7	1	3	1	6	4	2	50	102	1	5	4	2	51	95
CAW-02-01-5-1	1	6	1	2	1	5	1	1	50	106	1	7	1	1	51	93
CAW-02-02-5-1	1	5	2	1	1	5	1	1	50	101	1	7	1	1	50	91
CAW-02-02-6-3	1	5	2	1	1	1	1	1	48	102	1	8	1	1	48	91
CAW-02-03-10-6	1	3	2	3	1	2	1	1	51	103	1	5	1	1	47	96
CAW-02-03-10-7	1	4	2	4	1	2	3	1	51	106	1	6	1	1	47	97
CAW-02-03-15-4	1	4	1	2	1	3	1	1	46	107	1	5	1	1	47	98
CAW-02-04-8-3	1	5	2	2	1	4	1	1	49	106	1	6	1	1	49	102
CAW-02-04-7-7	1	6	1	1	1	4	1	1	51	100	1	5	1	1	51	98
CAW-02-04-3-5	1	4	2	2	1	4	1	1	51	102	1	4	1	4	48	99
Checks																
Red Wolaita	1	2	2	2	4.5	6.5	2	-	-	-	-	-	-	-	-	-
Omo-95(RWR-719)	1	4	2	2	1	3	1	-	-	-	-	-	-	-	-	-
Roba-1	1	2	2	3	-	-	-	-	-	-	-	-	-	-	-	-
DOR-554	1	4	2	2	-	-	-	-	-	-	-	-	-	-	-	-
DICTA-105	1	3	1	2	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviations: ALS= angular leaf spot, CBB= common bacterial blight, FLS=floury leaf spot, HB= halo blight, DF= days to 50% flowering, and DM=days to 50% pod maturity. Disease score using CIAT (1987) standard system.

Table 71. Days to flowering, maturity, seed mass and grain yield of top 10 small red F_5/F_6 bean lines selected from segregating populations and other nurseries.

Genotype	Days to 50 % flower	Days to 75% maturity	100-Seed mass (g)	Yield (kg ha^{-1})		
				PYT[a] (3 sites)	IYT[b] (2 sites)	Mean
ECAB 00421	45	87.9	27.6	2586	2393	2489
ECAB 00419	45	90	27.5	2362	2269	2316
ECAB 00413	43	87.3	26.5	2413	2182	2298
ECAB 00406	48.8	92.5	25.2	1860	2624	2242
ECAB 00426	45.9	89.7	27.4	2442	2028	2235
ECAB 00417	48	92.2	26.9	2148	2243	2196
ECAB 00420	44	86.7	26.3	2665	1631	2148
ECAB 00414	44	87.8	24.9	2247	2046	2147
ECAB 00422	44	90.7	26.9	2025	2250	2138
Trial mean	46.3	90.3	26.0	2067	1944	2005
Genotypes (G)	**	**	**	**	NS	
Locations (L)	**	**	NS	**	**	
G XL	**	**	**	**	*	
LSD $_{0.05}$	2.8	3.0	1.8	290.2	665	
CV(%)	5.4	2.9	6.0	19.9	34.3	

*,** : Significant at 5 and 1% probability levels, respectively; NS= not significant. PYT[a] = preliminary yield trial of F_5 ; IYT[b]= intermediate yield trial of F_6 and other advanced lines.

Table 72. Days to 50% flowering, maturity, seed mass and grain yield of advanced generation small red bean lines grown at two locations in Kenya.

Genotype	Days to flowering	Days to maturity	100-seed mass (g)	Grain yield (kg ha^{-1})		
				Kabete	Thika	Mean
ECAB 0429	43	85	26.9	2367	1482	1925
ECAB 0426	43	88	27.7	2111	1680	1895
ECAB 0420	44	86	28.5	1980	1646	1813
ECAB 0428	43	85	28.3	2052	1462	1757
ECAB 0424	45	86	28.1	2044	1308	1676
ECAB 0408	43	85	26.9	1782	1551	1617
ECAB 0410	45	86	27.4	1697	1590	1644
ECAB 0402	45	87	32.3	1992	1242	1617
Checks						
GLP 585	43	85	26.7	1741	1352	1547
Maasai Red	43	84	27.9	1787	1646	1717
Red Wolaita	44	85	25.9	1533	1408	1471
Mean (Thika)	43	85	25.0	-	1365	1365
Mean (Kabete)	44	86	30.9	1752	-	1742
Trial Mean	43	85	27.9	1752	1365	1554
CV (%)	8.0	1.9	5.7			31
Locations (L)	NS	**	**			**
Genotypes (G)	NS	**	**			NS
G x L	NS	NS	**			NS
Error						

*, **: Significant at 5 and 1% probability levels, respectively; NS= not significant

In Ethiopia, advanced medium and small red lines from the first regional nursery constituted in 2001, were evaluated at 13 sites representing a wide range of production zones. The most promising entries from national variety trials were DOR 527, DOR 711 and DOR 811. Farmers also evaluated and selected advanced lines in on-farm trials conducted in Melkassa, Awassa and Alemaya in participatory variety selection program (Assefa et al., 2007).

Two new regional small red nurseries were developed at Awassa between 2005 and 2008; the first nursery had 97 SNNPR lines, and second had 74 ETAW lines. The nurseries were distributed for further evaluation and identification of candidate varieties to programs in D. R. Congo, Kenya and Tanzania.

Regional Trials

Ninety-seven SNNPR lines and three checks were evaluated at Amaro in southern Ethiopia during the belg season. The 33 best yielding lines selected at Amaro were further evaluated in multi-location trials in nine environments in southern Ethiopia for two years. The test lines expressed highly significant variation for grain yield both at Awassa and Amaro. The mean yield ranged from 3531 (local) to 6355 (SNNPR-1-30) kg ha^{-1} at Awassa location and 178 (SNNPR-1-11) to 675 (SNNPR-1-29) kg ha^{-1} at Amaro test location. Sixteen test lines significantly out-yielded the best check DOR-554 (4556 kg ha^{-1}) at Awassa. At Amaro under severe drought conditions, five lines out yielded the best local check. Among checks used in the trial, local farmer variety performed better under moisture stress at Amaro.

Seventy 74 ETAW lines along with four checks were evaluated at Kokate (low soil P and N) in 2 m row plots using a lattice design with two replicates. The grain yield ranged from 1859 (ETAW-02-2-7) to 6537 kg ha^{-1} (ETAW-02-4-9). Thirty five lines performed better than the best check DOR-554.

In Madagascar, seven small red lines were selected. Grain yield of the selected lines varied from 771 to 1278 kg ha^{-1}. The selected lines were ECAB 0427 (771 kg ha^{-1}), ECAB 0418 (707 kg ha^{-1}), ECAB 0411 (1155 kg ha^{-1}), ECAB 0417 (1278 kg ha^{-1}), ECAB 0415 (1072 kg ha^{-1}), ECAB 0422 (824 kg ha^{-1}) and ECAB 0410 (780 kg ha^{-1}). This compared with 870 kg $ha^{-1}$for GLP 585. The selected lines flowered in 42 to 48 days in Madagascar. GLP 585, ECAB 0415 and ECAB 0410 flowered in 48 days. All other lines flowered in 42 to 43 days.

In Tanzania, 20 small red ECAB lines were evaluated for two seasons in Madiira. Growing conditions were favourable for plant growth and disease development. Results showed that test lines showed had intermediate to resistant reactions to rust and common bacterial blight. ECAB0411, ECAB0417 and MCM 2001 showed intermediate reactions to anthracnose. All other lines showed resistant reactions. Disease pressure was high for anthracnose, bean common mosaic virus and angular leaf spot. Diseases with the highest mean score on this trial were angular leaf spot (mean 4) and BCMV (mean 5). Nevertheless all genotypes showed resistant to intermediate reactions to diseases (scores 1-6), except entry Red Wolaita which was susceptible to BCMV. Flowering duration was between 41 and 48 days. Plant vigor ranged from 2.0 to 5. Nine lines had better yields compared to the check varieties (GLP 585, Red Wolaita and Maasai Red). The best yielding entries were ECAB0420 (4717 kg ha^{-1}), ECAB 0429 (4485 kg ha^{-1}), ECAB 0421 (4366 kg ha^{-1}), ECAB 0412 (4319 kg ha^{-1}), ECAB 0426 (4286 kg ha^{-1}) and ECAB0401 (4091 kg ha^{-1}). Yield of checks varied from 2.9 to 3.3 t ha^{-1} in these trials.

Regionally, four new lines were selected in the three countries. These were ECAB 0418, ECAB 0411, ECAB 0417 and ECAB 0410. Eight lines were selected in two of the three countries. Three lines were selected in one country.

Variety Release: Several varieties have been released in countries where this grain type is important (Table 73). Melka Dima (XAN 310) was released in Ethiopia in response to demand for a cover crop that reduces loss of soil moisture. It is high yielding and resistant to common bacteria blight. Nasser (DICTA 105) is high yielding, resistant to common bacterial blight and early maturing. Omo 95 (RWR 719) was selected during the participatory breeding program in southern Ethiopia. It has light red seeds that cook fast. Omo 95 is high yielding, resistant to common bacterial blight and root rots. It has been reported to be drought tolerant in southern Ethiopia. Batagonia is a red seeded, high yielding climbing bean variety, and probably the first formally released climbing bean in Ethiopia.

Table 73. Small and medium red varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Country of release
Melka Dima	XAN 310	2006	Ethiopia
Dinknesh	RAB 484	2006	Ethiopia
Wairimu Dwarf	-	2007	Kenya
Batagonia	RWV 482	2004	Ethiopia
Omo 95	RWR 719	2003	Ethiopia
Nasser	DICTA 105	2003	Ethiopia
Dimtu	DOR 554	2003	Ethiopia
Menakely*	Local landrace	2007 (pre-release)	Madagascar

* Madagascar has no formal variety release system and is working with ECABREN to develop release procedures.

Contributors: Paul Kimani, Asrat Asfaw and Teshale Assefa (Ethiopia)

Collaborators: Sostenes Kweka (Tanzania), Hery (Madagascar), Beam Teams at Kabete (Kenya), Selian (Tanzania), Awassa (Southern Ethiopia), FOFIFA (Madagascar), Melkassa (Central Ethiopia) and Mulungu (D. R. Congo)

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2.3.6 Development and release of brown and tan colored bean varieties with multiple stress resistance in eastern Africa

Rationale: Brown, tan and yellow beans account for about 11% of Africa's bean production. They are grown on 290,000 ha in eastern Africa and 90,000 ha in southern Africa. They are of high to moderate importance in southwest Kenya, along Lake Tanganyika region in Tanzania, eastern D. R. Congo, Rwanda, Burundi, Uganda, southern Sudan, Madagascar and southwest Cameroon. In the Great lakes region, brown and tan colored beans are part of popular mixtures. In southern Africa, brown, tan and yellow beans are important in Angola, Zambia, northern Mozambique, Swaziland and Lesotho. Some small seeded types such as 'Ubososera' are tolerant to soil acidity. Carioca types have high yield potential but average market potential in the region. However, they are a potential food security crop for smallholder, resource poor farmers because of their plasticity and good performance in marginal environments. Carioca bean may have potential in niche markets. For example, carioca grain type has been in high demand in the Copper Belt of Zambia and sugar estates of Swaziland which are under-exploited markets for ECABREN countries. However, available cultivars of brown, tan and yellow beans are susceptible to angular leaf spot, anthracnose, root rots, rust, and halo blight, low soil P and nitrogen and Al/Mn toxicity. These factors contribute to the low production and inability to meet demand in domestic and regional markets. Although these grain types are important to smallholder farmers, little effort has been devoted to their improvement in Africa. Regional programs were therefore started in 2001 to develop improved cultivars of these grain types with a high yield potential, a combination of tolerance to three or more biotic and abiotic stresses and grain characteristics acceptable to consumers in target markets. The main achievements of these programs are presented briefly in this report.

Materials and Methods: Brown, tan, yellow and carioca bean grain types were selected from F_2 and F_3 segregating populations at Kabete. The populations were derived from multi-parent crossing program, which included lines with known tolerance to major biotic and abiotic stresses (Kimani et al., 2004; Lunze et al., 2007). The selections were grown in progeny rows at Kabete to increase uniformity within families and to expose them to disease and drought stress. F_5 and F_6 lines were grown in preliminary and intermediate yield trials at three locations in Kenya including Thika. Thirteen lines selected in advanced yield trials and lines from other multiple constraint nurseries were used to constitute a regional nursery. The regional nursery was distributed for further evaluation to member countries interested in these grain types between 2000 and 2005 (CIAT 2000, 2001, 2002, 2003, 2004 and 2005).

Breeding populations were also generated at INERA -Mulungu Research Station in eastern D. R. Congo. This program started in 2001, and focused on improving resistance to angular leaf spot (ALS) in three locally popular but susceptible cultivars: Kirundo (yellow), Munyu (brown) and Nakaja (tan). Six hundred sixty-nine pollinations were made with A285, A235, Mex 54, G5686, MLB-36-89A and A339 as sources for resistance to ALS. Other resistance sources used were: G11727, ACC 714 and Besh-Besh for bean stem maggot. VEF(88), LPY6, CIM 9314, LSA 32 and PAN 150 were used a sources of resistance to low N, P and low pH complex. These sources were combined in complex crosses and backcrossed to the three recurrent parents. Early generation (F_2 to F_4) populations were evaluated for resistance to angular leaf spot, root rots, anthracnose and common bacterial blight in disease 'hot spots'. F_5 and F_6 generations were evaluated for grain yield and other agronomic traits in replicated trials at 2 to 4 locations in Kenya and D. R. Congo. Selected lines with multiple constraint resistance were subjected to participatory selection with men and women farmers to identify lines that met breeder, farmer and consumer criteria in F_7 and F_8 generations. Gofta, a brown seeded variety released in Ethiopia, line A197, Kirundo, and other yellow and tan colored local varieties were included as checks. Standard agronomic practices were followed. Best performing lines were entered in multi-location national variety yield trials to identify candidates for release in collaborating countries.

Results and Discussion: ECAB 0761 showed an intermediate reaction to root rot at Thika. All other genotypes showed resistant reaction to angular leaf spot, anthracnose and rust. Genotypes flowered and matured earliest at Thika and later at Kabete. Average duration to maturity was 87 days at Kabete compared to 82 days at Thika. Average pod yield was 161 pods m^{-2} at Thika compared with 162 pods m^{-2} at Thika. Mean seed mass was highest at Kabete (30.8 g per 100-seeds) and lowest at Thika (24.1 g per 100-seeds). Mean grain yield was highest at Juja. Only four lines produced higher grain yield than A197 (Table 74). Five new lines had higher grain yield than Gofta. However, the yield advantage was modest.

In eastern D. R. Congo, two lines DRK 7 (1620 kg ha^{-1}) and MAC 16 (997 kg ha^{-1}) had higher yields than the best check, MLB 118/96B (943 kg ha^{-1}) in preliminary yield trials. However, seven lines had better yields than the second check, Kirundo (623 kg ha^{-1}). The selected lines showed better tolerance to biotic and abiotic stresses compared to the checks. In the confirmatory yield trial (CYT), nine lines retained their superior performance compared to Kirundo (check). These were MLB 118/94B (1693 kg ha^{-1}), CODMLB 001/03 (1690 kg ha^{-1}), LSA 144 (1624 kg ha^{-1}), COD MLB 007/03 (1605 kg ha^{-1}), MLB 174/94B (1557 kg ha^{-1}), COD MLB 033/03 (1489 kg ha^{-1}), CODMLB 005/03 (1482 kg ha^{-1}), M'Sole (1301 kg ha^{-1}) and COD 037/03 (1210 kg ha^{-1}). In these trials Kirundo had a yield of 1198 kg ha^{-1}. Fifteen bush bean lines were tested for consumer and farmer acceptability at five sites in South Kivu. Seven were selected as potential candidates for release. In descending order of acceptability, they were: ZKA 93-10M/95 (30% acceptability), SCAM 80 CM/2 (22%), KS 65-2 (18.5%), RWR 1873 (11%), LSA 60-1 (11%), G5686 (3.7%) and MCD 2518-[1] (3.7%).

Table 74. Mean duration to flowering, maturity, pods m^{-2}, 100-seed mass and grain yield of selected F_8 brown, yellow and tan colored bean lines grown at four environments in Kenya.

Genotype	**Days to 50% flower (d)**	**Days to maturity (d)**	**Pod m^{-2}**	**100-seed mass (g)**	**Grain yield ($kg\ ha^{-1}$)**			
					Kabete LR	**Thika SR**	**Juja SR**	**Mean**
ECAB0755	44.0	84.6	207.9	23.0	1646	2658	1325	1876
ECAB0753	44.0	83.7	208.4	21.8	1666	2078	1763	1836
ECAB0761	42.8	83.6	211.6	22.3	1302	2773	1397	1824
ECAB0758	42.7	83.0	204.4	28.6	650	2322	2076	1683
A 197	41.7	82.7	205.2	48.8	1387	1633	1953	1658
ECAB0757	43.8	85.5	219.8	25.9	1320	2247	1400	1656
GOFTA	41.9	82.8	184.2	29.4	1197	2587	1175	1653
ECAB0756	43.5	84.9	219.0	21.6	1206	2510	1206	1641
ECAB0752	44.2	85.3	198.5	25.5	890	2657	1333	1627
ECAB0763	45.5	85.8	199.3	24.1	922	2512	1417	1617
ECAB0760	43.7	84.9	201.7	25.6	1182	2488	1147	1606
Environmental mean	43.8	84.6	201.7	26.6	1117	2373	1395	1628
CV(%)	3.7	2.2	16.1	5.7				17.4
Genotypes (G)	**	**	NS	**				**
Environments (E)	**	**	**	**				**
G x E	NS	**	*	**				**

*, **: Significant at 5 and 1 % probability levels, respectively; NS= not significant, LR= long rain (April-July), SR= short rain seasons (Nov-December).

In western D. R. Congo, bean germplasm was introduced to INERA-M'vuazi in western D. R. Congo from INERA research stations at Mulungu, Gandanjika, FOFIFA (Madagascar) and University of Nairobi (Kenya) from 2000 (Kimani, 2006). The collection comprised of 80 sugar bean lines and 40 BILFA 5 nursery lines from Mulungu, 8 entries from FOFIFA bean program, more than 86 F_2 and F_3 segregating populations from the regional multiple constraint nurseries at University of Nairobi, and local collections. The collection was evaluated at M'vuazi, Kisantu and several on-farm sites in Bas Congo, Kinshasa and Bandu Provinces. All trial sites were below 1000 masl. The evaluations were conducted in collaboration with farmer groups, NGOs and community based organizations (CBOs).

<u>Variety Release:</u> Table 75 shows some of the tan, yellow and cream colored varieties released in eastern Africa between 2003 and 2008. 'Wedo' is a medium seeded, high yielding cream/light tan colored variety with combined resistance to common bacterial blight and rust. 'Haramaya' is a large seeded variety with light tan seeds. It was released by Haramaya University (formerly 'Alemaya University') for production

in eastern Ethiopia. Inamunihire is yellow seeded determinate bush variety. It is high yielding and has good taste and other cooking characteristics. 'Lumbua' is a tan seeded bush (type 1) variety with combined resistance to common bacterial blight and web blight. It is tolerant to heat, low soil nitrogen, phosphorus and potassium. 'Sepe' has large tan colored seeds. It is a bush variety with combined tolerance to web blight, common bacterial blight, heat, low soil nitrogen, phosphorus and potassium. 'Manseki' is yellow seeded climbing bean variety with combined resistance to common bacterial blight, web blight, heat and low soil fertility. It is a large seeded tan colored bush (type 1) variety adapted to hot humid lowlands of western D. R. Congo. It is resistant to common bacterial blight, and tolerant to heat and low soil fertility. G22501, BF 10 and BF 12 are cream seeded varieties with resistance to common bacterial blight, tolerance to web blight, bean stem maggot, heat and/or low soil fertility. They have type 1 growth habit. RWR 2172 and RWR 2154 have medium, cream seeds, and determinate bush growth habit.

Table 75. Brown, tan and yellow seeded varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Country of release
RWR 2154	ISAR line	2006	Rwanda
MAM 48	MAM 48	2003	Ethiopia
Wedo	MAM 41	2003	Ethiopia
Inamunihire	IZ 0201245	2003	Burundi
IZ 0201513	IZ 0201513	2003	Burundi
Mbidi	Local landrace	2005	D. R. Congo (west)
Lumbua	L4	2005	D. R. Congo (west)
Sepe	G8047	2005	D. R. Congo (west)
Manseki	Landrace	2005	D. R. Congo (west)
I 7	Landrace	2005	D. R. Congo (west)
G22501	G22501	2005	D. R. Congo (west)
BF12	BF12	2005	D. R. Congo (west)
BF10	BF10	2005	D. R. Congo (west)
RWR 2172	ISAR line	2004	Rwanda
MAM 48	MAM 48	2003	Ethiopia
Wedo	MAM 41	2003	Ethiopia
Inamunihire	IZ 0201245	2003	Burundi
IZ 0201513	IZ 0201513	2003	Burundi

Source: National Bean program reports, 2003-2008

Contributors: Paul Kimani, Nkonko Mbikayi and Lodi Lama (INERA, D. R. Congo), Teshale Assefa (EAIR, Ethiopia), Capitoline Ruradama (ISABU, Burundi), Félicité Nzanzebara (ISAR, Rwanda).

Collaborators : Bean Teams at Kabete (Kenya), Mvuasi and Mulungu (D. R. Congo), Melkassa (Ethiopia), Alemaya University, Bujumbura (Burundi) and Rubona (Rwanda).

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2.3.7 Development and release of improved climbing bean varieties in eastern Africa

Rationale: Although climbing beans a relatively recent introduction in most of the countries in East and Central Africa, they have gained popularity in the last decade among smallholder farmers because of their conspicuous yield advantage over bush types, and more effective and efficient utilization of cultivated plots which are decreasing rapidly in size due to fast population growth. Climbing beans, which were introduced in Rwanda in mid 1980’s spread rapidly to Burundi, D. R. Congo, Uganda, Kenya, Tanzania and Ethiopia. However, continued expansion and adoption of climbing bean technology is constrained by susceptibility of available cultivars to anthracnose, angular leaf spot, root rots complex, aschochyta, common bacterial blight, halo blight, low soil N and P drought and lack of preferred grain types. Expanding cultivation of climbing beans from their traditional production high altitude zones with adequate rainfall, moderately fertile soils and high population pressure to the less densely populated and more expansive middle altitudes is constrained by poor adaptation of popular cultivars, moisture, heat and low soil fertility stresses. Spread of climbing beans to regions where traditional mixtures do not adequately meet new market demand for specific seed types has put pressure on national programs to develop cultivars that respond better to these demands. A regional program was therefore initiated in 2000 to develop high yielding, marketable climbing beans cultivars with resistance to two or more biotic stresses and wider adaptation. In this report, we highlight major milestones reached in development and release of improved climbing beans in east, central and west Africa between 2003 and 2008.

Materials and Methods: A working collection was made from climbing bean genetic resources maintained by CIAT, Colombia and the national program of Rwanda, which has the regional mandate for development of climbing beans. Additional germplasm was received from national program of D. R. Congo. The collection included entries from CIAT’s core collection, advanced breeding lines, landraces and commercial cultivars. Parental lines were selected for the crossing programs at Kabete (Kenya) and Rubona (Rwanda). Crosses were made to incorporate root rot, fusarium wilt, angular leaf spot, and anthracnose resistance and red mottled seed type into popular and well-adapted climbers. Adapted parents included Umubano, Vunikingi, Ngwinurare, Puebla and Urugezi. Umubano is resistant to anthracnose but susceptible to fusarium wilt. Vunikingi is high yielding and resistant to root rots, fusarium wilt and anthracnose. However, its small pink seeds are not popular in major markets in the region. Ngwinurare was included in the crosses because of its large red seeds popular in certain market sectors. It is not resistant to priority constraints. Puebla is tolerant to low soil fertility. Mexico 54 provided resistance to angular leaf spot, and SCAM 80/CM 15 resistance to root rots. Rubona 5, PVA 8 and Urugezi are popular red mottled cultivars but susceptible to anthracnose, angular leaf spot, fusarium wilt, and root rots. These parental lines were combined in single, three way and double crosses (Table 76). More than 691 pollinations were made at Kabete to create populations segregating for red mottled, red kidney and other priority seed types and resistance to angular leaf spot, anthracnose, root rots and fusarium wilt.

Screening for multiple disease resistance. Both advanced lines and segregating populations were screened for multiple disease resistance in Rwanda, Kenya and D. R. Congo. In Rwanda, 11 F_2 populations were divided into four portions and their F_3, F_4, F_5 and F_6 progenies screened in a systematic rotation in disease hot spots at Rubona (angular leaf spot), Rwerere (anthracnose), Gikongoro (root rots) and Ntendezi (fusarium wilt and anthracnose). Disease pressure was moderate at Rwerere (2300m), high at Rubona (1650m), and very high at Ntendezi (1600m) and Gikongoro (2300m). At each planting cycle, pedigree selection method was used to obtain diseases resistant plants based on a severity score rating of 3 or less on a CIAT scale of 1-9. Sixty-six F_7 lines resistant to 2 or more diseases and different market seed-types were planted in replicated yield trials at Rwerere and Rubona sites representing the high (2300 m) and mid altitude (1650 m) zones.

Table 76. Multiple constraint resistance climbing bean populations created at ISAR, Rubona.

Population Code	Pedigree
MMCR-RW-1	Ngwinurare/SCAM 80CM-15//Ngwinurare/Puebla
MMCR-RW-2	Ngwinurare/Puebla// Mex 54
MMCR-RW-3	Umubano/SCAM 80 CM-15//Umubano/Ngwinurare
MMCR-RW-4	Umubano/SCAM 80 CM-15//RWR13121
MMCR-RW-5	Umubano /Mex 54
MMCR-RW-6	Vuninkingi/Mex 54
MMCR-RW-7	Urugezi/Puebla
MMCR-RW-8	Umubano/Urugezi//Mex 54
MMCR-RW-9	Vuninkingi/Urugezi//Umubano
MMCR-RW-10	Umubano/Vuninkingi
MMCR-RW-11	Umubano/Vuninkingi // Umubano

Source: Musoni, 2007.

In Kenya, 75 advanced lines and segregating populations were evaluated at Kabete, Thika, Ol Jorok and Embu. Ol Jorok (2350m) received heavy rainfall from planting to mid-pod filling, creating favourable conditions for disease development. At Embu, participatory selection was conducted among 25 F_4 segregating populations of medium altitude climbers from CIAT, Colombia and from the regional climbing bean nursery. Preliminary evaluation for morphological traits (growth habit, pod clearance and plant height) and yield components was conducted on-station during the long rain season. During the following short rain season, representative farmer groups from Meru, Embu and Kirinyaga districts were invited to evaluate and select single plants ($F_{4.6}$) with preferred traits. Farmers agreed on the most important selection criteria. Progeny rows of the $F_{4.6}$ lines were established at the station during the following long rain season to produce adequate seed for on-farm testing. About 32 $F_{4.7}$ lines were subsequently evaluated on-farm and on-station in the three districts. Five lines were selected for national performance trials which were conducted at seven sites (Katumani, Thika, Embu, Eldoret, Njoro, Kakamega and Kapsabet) over two years (CIAT, 2007).

Between 2003 and 2007, the regional nursery was also distributed for further evaluation and selection by programs in D. R. Congo, Uganda, Tanzania, Madagascar, Burundi, Cameroon and Ethiopia. Additional crosses were generated at INERA- Mulungu (D. R. Congo) and selected for multiple resistance to common bacterial blight, angular leaf spot and tolerance low fertility acid soils (Mbikayi and Kimani, 2004).

Results and Discussion: The eleven bi-parental and multi-parent populations developed at Rubona showed considerable segregation for grain type, growth habit and disease resistance (Tables 77 and 78). Thirty-eight $F_{2.6}$ lines combining resistance to two or more diseases and high yield potential were selected (Table 79). Fourteen lines showed adaptation to medium altitude zones, 15 to high altitude zones and nine to both medium and high altitude zones. Thirty-two lines combined multiple diseases with the preferred red and red mottled grain types. Results showed that Gikongoro and Ntendezi were good hot spots for the selection against root rots while Rubona was ideal for the selection against angular leaf spot. However, Rwerere was not as reliable as Ntendezi for the selection for anthracnose resistance. The new elite lines with a yield range of 2.5 ton ha^{-1} to 4.5 ton ha^{-1}, or 101-141% of the yields of improved checks were selected at Rwerere and Rubona (Tables 80a, b, and c). The bush bean cultivar, SCAM 80 CM / 15 was the most effective donor of the red-mottled seed coat color compared with Urugezi and RWR 1312. Sixty-five per cent of the new red and red mottled climbing bean lines were large seeded.

Table 77. Combinations seed color and disease resistance observed in 11 populations developed from simple and multiple parent crosses at ISAR Rubona station.

Population	Seed color		Disease resistance			
	Red mottled	Red	Anthracnose	Angular leaf spot	*Pythium* root rot	*Fusarium* wilt
MMCRW-1	+	+	-	+	+	+
MMCRW -2	-	+	+	+	+	+
MMCRW -3	+	+	-	-	+	+
MMCRW -4	+	+	+	+	+	-
MMCRW -5	-	+	+	+	-	-
MMCRW -6	-	-	+	+	+	+
MMCRW -7	+	-	-	-	+	+
MMCRW -8	+	+	+	+	+	+
MMCRW -9	+	+	+	-	+	+
MMCRW -10	-	+	+	-	+	+
MMCRW -11	-	+	+	-	+	+

+ = trait observed, - = not observed.

Table 78. Distribution of new climbing bean lines selected from 11 populations by market class.

Population	Red	Red-mottled	Purple	Cream	Black	Total
MMCRW-1	11	18	4	3	2	39
MMCRW-2	0	0	1	1	0	2
MMCRW-3	0	4	0	0	0	4
MMCRW-4	0	1	0	0	0	1
MMCRW-5	1	0	2	0	3	6
MMCRW-6	0	0	4	0	0	4
MMCRW-7	0	3	0	0	1	4
MMCRW-8	0	0	0	0	0	0
MMCRW-9	0	4	0	0	0	4
MMCRW-10	0	0	2	0	1	2
MMCRW-11	0	0	0	0	0	0
Total	13	30	12	4	7	66

Table 79. Mean yield of new climbing bean lines selected for multiple disease resistance at Rubona and Rwerere ISAR stations.

Market class	No. of lines	Grain yield (kg ha^{-1}) by site		
		Rubona	Rwerere	Mean
Reds	13	2232	2771	2505
Red mottled	30	2416	2521	2468
Purple	12	1421	2799	2110
Cream	4	1386	2306	1847
Black	7	1771	2736	2254
Parents	7	1838	1938	1886
Checks	2	1678	2663	2171

Table 80a. Disease score, market class and yield advantage of new climbing bean lines at Rubona, Rwanda.

Seed color	Population	Variety	Disease severity			Yield increase above check (%)
			Anth.	ALS	Root rot	
Red	MMCRW-1	RWV 2573	1	3	2	141
		RWV 2575	1	3	2	126
		RWV 2581	1	4	3	131
		RWV 2599	1	4	2	107
		RWV 2606	1	4	4	111
Red mottled	MMCRW-9	RWV 2676	1	4	3	155
	MMCRW-1	RWV 2680	1	3	4	103
		RWV 2681	1	4	4	130
		RWV 2682	1	3	4	158
		RWV 2697	1	4	4	109
	MMCRW-2	RWV 2698	1	4	4	110
	MMCRW-7	RWV 2694	1	2	2	129
		RWV 2695	1	4	3	112
Black	MMCRW-5	RWV 2856	1	3	4	102

Table 80b. Disease score and yield advantage of new climbing bean lines selected for multiple disease resistance at Rwerere, Rwanda.

Seed color	Population	Variety	Disease severity			Percent yield advantage over check (%)
			Anth.	ALS	Root rot	
Red	MMCRW-1	RWV 2572	1	3	4	151
		RWV 2573	1	4	2	125
		RWV 2575	1	3	2	105
		RWV 2581	1	4	3	108
		RWV 2594	1	4	4	107
		RWV 2599	1	4	2	100
Red-mottled	MMCRW-1	RWV 2680	1	3	4	115
		RWV 2691	1	3	4	101
		RWV 2697	1	4	4	122
	MMCRW-7	RWV 2694	1	3	2	111
		RWV 2695	1	4	3	109
Purple	MMCRW-10	RWV 2654	1	4	4	134
Black	MMCRW-7	RWV 2851	1	3	4	107
	MMCRW-5	RWV 2852	1	3	4	106
	MMCRW-5	RWV 2856	1	3	4	118

Table 80c. Disease score, market class and yield advantage of new climbing bean lines selected for multiple disease resistance at Rubona and Rwerere trial sites, 2005-2007.

Seed color	Source population	Variety Code	Disease severity rating			Yield advantage over check (%)	
			Anthracnose	Angular leaf spot	Root rots	Rubona	Rwerere
Red	MMCRW-1	RWV 2573	1	3	2	141	125
		RWV 2575	1	4	2	126	105
		RWV 2581	1	3	3	131	108
		RWV 2599	1	4	2	107	100
Red mottled	MMCRW-1	RWV 2680	1	3	4	103	115
		RWV 2697	1	4	4	109	122
	MMCRW-7	RWV 2694	1	3	2	129	111
		RWV 2695	1	4	4	112	109
Black	MMCRW-5	RWV 2856	1	3	4	102	118

At Ol Jorok (Kenya) test lines showed delayed flowering (64 to 94 days) compared with 40 to 49 days at Kabete and Thika (Table 81). Most of the lines were attacked severely by anthracnose, web blight, angular leaf spot, CBB, BCMV, ascochyta and halo blight or a combination of these diseases. However, a few lines were either completely free of the diseases or showed very low levels of infection. Eleven lines were selected because of their vigor and low infection. These were: MLV-76/97A, VCB 87012, AND 10, VCB 81012, MLV 198/97A, MLV 222/97A, MLV 227/97A, MLV 216/97A, G24517, Urugezi and G20751. Urugezi showed moderate infection by viruses. Umubano and Vunikingi were susceptible to BCMV. Lines apparently adapted to conditions prevailing at the three sites were: G24517, G20751 and Urugezi.

At Embu, the F_4 populations segregated for a wide range of grain types, which included red mottled, red kidney, small reds, pinto, sugars and yellows. The lines also showed considerable variation in duration to maturity, plant height, vigor, pod load and grain yield (Table 82). The broad variation observed in these populations suggested possible outcrossing, in addition to the expected segregation. Some lines showed instability with segregation persisting in $F_{4.7}$ and $F_{4.8.}$ For example, selections from MAC 26 continued to segregate for grain type even in advanced generations. Pinto, grey (mwezi moja type), yellow pinto and red mottled types could be identified from progeny rows in $F_{4.8}$ generation. Grain yield varied from 800 to 3800 kg ha^{-1}. Duration to maturity varied from 80 to 108 days at Embu (about 1550 m). Twenty-two bean $F_{4.6}$ lines combining preferred grain, yield and plant traits were selected. Five lines (Table 82) were registered for national performance trials. Results showed that Umubano and Vunikingi were very susceptible to BCMV (score of 9) at Thika and Kabete. MAC 34 showed intermediate reaction to rust and angular leaf spot. MAC 13, MAC 34 and MAC 64 showed outstanding performance across agro-ecological zones.

<u>Release of New Varieties:</u> Considerable progress has been made in development and popularisation of climbing bean varieties in east and central Africa in the last five years. Nearly all countries are evaluating or have released improved climbing varieties. Table 83 shows some of the new climbing bean varieties released in eastern Africa between 2003 and 2008.

Table 81. Duration to 50% flowering, seed size, grain type and reaction to bean common mosaic virus, web blight and common bacterial blight of 26 climbing bean lines selected at Ol Jorok, Kenya.

Line	Days to flowering	Seed size	Grain type	*CBB	*BCMV	Web blight	Other observations
MLV 59/97A	72	M	sugar	5	2	4	
MLV 76/97A	63	S	brown	1	1	2	
Kirundo	76	L	yellow	1	7	1	Susceptible to ALS
VCB 87012	70	M	brown	1	1	1	
Nakaja	57	S	brown	1	5	1	vigorous
AND 10	85	L	sugar	1	1	1	vigorous
VCB 81012	61	S	brown	1	7	1	
M'Sole	76	S	brown	1	2	2	
AFR 441	71	M	zebra	1	1	3	
MLV 198/97A	71	S	zebra	2	1	3	
MLV 6/90B	71	S	brown	1	1	9	
MLV 222/97A	69	S	white	1	1	1	vigorous
MLV 56/96B	62	S	brown	1	5	1	
MLV 227/97A	63	S	brown	1	1	1	
MLV 216/97A	85	S	black	1	1	1	
Cuarentino 0817	63	S	white	1	1	1	
SEQ 1006	70	L	zebra	1	3	4	
G59/1-2	71	L	brown	2	7	1	
Nain de Kyondo	76	S	white	1	2	1	
G50330	94	M	brown	1	2	1	
G24517	76	M	yellow	3	1	1	
G20875	86	L	brown	1	7	1	
Gisenyi	91	L	sugar	1	2	1	
G20833	85	S	black	3	9	1	
G31479	76	M	black	2	7	1	
G20751	84	M	yellow	2	7	1	

Seed size: S= small (< 25g/100 seeds), M= medium (25-39 g/100 seeds) and L=large (> 40 g/100 seeds)
* CBB= common bacterial blight, ALS= angular leaf spot and BCMV= bean common mosaic virus.

Table 82. Some characteristics of five climbing bean lines selected in advanced yield trials in Kenya.

Genotype	Duration to flowering	Duration to maturity	Grain type	Grain yield (kg ha^{-1})
MAC 13	48	99	Medium, red round seeds	3000
MAC 34	48	91	Medium, red mottled	3600
MAC 64	40	88	Red mottled	4100
MAC 26	48	91	Segregating for pinto, red and yellow grain types	2667
RWV 524B	49	102	Red kidney, large seeded, heavy podding	3000
Checks				
Umubano	48	95	Small, glossy red	2933

Table 83. Climbing bean varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Country of release
Kenya Mavuno	MAC 64-1	2008	Kenya
Kenya Safi	MAC 13-3	2008	Kenya
Kenya Tamu	MAC 34-5	2008	Kenya
Cheupe	CAB 19	2008	Tanzania
M 211*	M211	2008	Madagascar
Kayana*	Kayana	2008	Madagascar
VNB 81010*	VNB 81010	2008	Madagascar
RWV 1365*	RWV 1365	2008	Madagascar
MLV 198/97A*	MLV 198/97A	2008	Madagascar
G 59/1-2*	G59/1-2	2008	DRC (west)
VCB 81013*	VCB 81013	2008	DRC (west)
LIB 1*	LIB 1	2008	DRC (west)
Kiangara*	MLV 59/97A	2008	DRC (west)
RWV 1892	RWV 1892	2007	Rwanda
RWV 2070	RWV 2070	2007	Rwanda
RWV 1892	RWV 1892	2007	Rwanda
CODMLV 052*	CODMLV 052	2007	DRC (east)
CODMLV 056*	CODMLV 056	2007	DRC (east)
MLV 224/97A*	MLV 224/97A	2007	DRC (east)
MLV 198/97A*	MLV 198/97A	2007	DRC (east)
MLV 59/97A*	MLV 59/97A	2007	DRC (east)
Batagonia-1	RWV 482	2004	Ethiopia
MAC 28	MAC 28	2004	Rwanda
NABE 12C	Sugar 131/MAC 31	2003	Uganda
Ndamirabashonji	RWV 167	2003	Rwanda
Amakwamirire	RWV 296	2003	Rwanda

Source: National Bean program reports, 2003-2008
* Pre-releases.

Contribution: Paul Kimani (CIAT), Matthew Blair (CIAT), Augustine Musoni (ISAR, Rubona), Nkonko Mbikayi (INERA, D. R. Congo), Lodi Lama (INERA, D. R. Congo), Teshale Assefa (EIAR, Ethiopia), Annet Namayanja (NARO-NACRRI, Uganda), Festo Ngulu (SARI, Tanzania) and Heri Andriamazaolo (FOFIFA, Madagascar).

Collaborators: Bean Teams in Kenya, Rwanda, D. R. Congo, Madagascar, Ethiopia and Uganda

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2.3.8 Breeding for specific bean market classes within Southern Africa Bean Research Network (SABRN)

Rationale: Within the SABRN, not all NARS programs have the capacity to generate segregating populations of their own. The countries that have active breeding programs include, Malawi, South Africa, southern highlands of Tanzania, Zambia and Zimbabwe. All these NARS bean breeding programs have embraced the market class breeding program initiative, where each country concentrates on a market class or two, usually focusing on market classes which are important to the nation, and improve them for specific biotic and or abiotic stresses of importance to the nation as well as to the region. The resulting germplasm is shared to all NARS programs with interest in the said market classes. In this reporting period, a number of countries in the region, including the back-up regional breeding program had developed segregating populations and lines which combined specific market classes and one or more biotic and or abiotic stresses:

Progress in breeding for market classes

- In Malawi, the focus is on red kidney, khaki, red mottled (calima) market classes, and important stresses are common bacterial blight (CBB), angular leaf spot (ALS), halo blight (HB), and low soil fertility (LSF). Many lines in these market classes developed by the national program were in preliminary trials (PYT) and some in advanced yield trials (AYT). In addition, there were some sugar lines, which were developed using molecular tools (marker assisted selection) in collaboration with Washington State University.

- In South Africa, the focus is on sugar and navy bean, targeting such stresses as: ALS, CBB, Rust, bean common mosaic virus (BCMV) and halo blight (HB). During reporting period there were over 1800 lines in different generations (F_3 - F_6), and in different populations which combined sugar bean market class with various multiple stresses like: CBB/rust/ALS/BCMV; Rust/ALS/BCMV; Rust/CBB/BCMV and Rust/BCMV. Likewise there were several lines at different generations which combined navy bean market classes with different combination of biotic stresses. In addition some lines were in check-row trials, and many others in replicated yield trials. Some of the lines in different market classes, which were developed for rust and ALS or rust and halo blight (HB) or only rust resistance were sent to the SABRN regional coordinator for seed increase and distribution to other interested NARS programs within the region. The southern highlands of Tanzania (SHTZ) focus on such market classes as: red beans (small, medium and large) and yellow beans, targeting such traits as: ALS and anthracnose (ANTH). There are several lines in the red market class which were in F_5, F_6, F_7 and F_8 generation. Some of these lines are ready for distribution to various interested NARS partners in SABRN or beyond. The progenies in the yellow bean market class are at F_4 generation. They also had some calima bean lines which were doing very well in the SHTZ environments and they were ready to share the lines with other national programs.

- In Zambia, the focus is on yellow and brown/tan (khaki), targeted such traits as: ALS and CBB. They had over 300 lines at various F_3, F_4, BC_1 and BC_2 in different populations combining different parental sources for the market class and donor parents for ALS and CBB resistance.

- In Zimbabwe, the target market classes were: red beans (large red kidney, medium and small red) and sugar bean, targeting such traits as: ALS and CBB for biotic and drought and low P for abiotic stresses. They had a total of 56 lines from 13 populations at F_5 generation.

- The regional network breeding program has a back-up breeding program to support the NARS breeding programs in various market classes: red mottled, brown/khaki, sugar, reds, and purples.

The targeted stresses include; ALS, CBB, bean stem maggot (BSM), low P and drought. During this reporting period, there were over 20 populations at F_3-F_5 generation combining red mottled market class with various stresses such as ALS, CBB, BSM and low P. In addition there were 300 lines at F_7 and above. In the brown/khaki market class, there were 10 populations in F_2-F_3 generations and 70 lines at F_7 generation combining grain type with ALS, CBB, BSM and drought. In addition there were over 100 lines in red kidney, 80 lines in sugar and 70 lines in purple, all at F_7 generation and above. These lines are ready for distribution to NARS partners within SABRN and others.

Results and Discussions: The active national breeding programs in SABRN are making progress in generating segregating populations in different bean market classes, to improve them for resistance to various biotic and abiotic constraints. The segregating populations were at different generations, ranging from F_2 through F_7 and above. In some countries like Malawi, South Africa and southern highlands of Tanzania, they also had some fixed lines which were already in preliminary and advanced yield trials. These countries were ready to share the segregating populations as well the fixed lines with others in the network, who are interested in the available market classes. This is particularly useful to national programs which have interest in several bean market classes, but they do not have the resources and capacity to run breeding programs in all market classes. Thus sharing breeding responsibility among various NARS programs, and exchange of resulting germplasm becomes a key to ensure that a number of bean market classes are included in the breeding programs across the region – unleashing the power of networks.

Contributor: R. Chirwa

Collaborators: A. Liebenberg, M. Liebenberg, D. Fourie, J. Bokosi, C. Madata, G. Makunde, K. Muimui, S. Beebe, M. Blair, R. Buruchara, P. Kimani

2.3.9 Developing bush and climbing bean lines with resistance to *Pythium* root rot, angular leaf spot, and bean common mosaic and necrotic viruses

Rationale: *Pythium* root rots and angular leaf spot (ALS) are some of the important diseases affecting bean production in Africa, particularly, on major commercial and adapted bush and climbing bean cultivars. At the same time, some of the good sources of resistance to other diseases are either susceptible (e.g. CAB 19, G2333) to bean common mosaic (BCMV) and bean common mosaic necrotic virus (BCMNV) or have the dominant "*I*" gene (RWR 719, RAB 487, RWR 2075, RWR 1946) which confers resistance to a wide range of BCMV strains. However, BCMNV strains induces the lethal black root hypersensitive resistant (HR) reaction on germplasm with "*I*" gene and therefore limits their usefulness. To provide stable, broad-based resistance to the latter, a suitable strategy is to protect the "*I*" gene by combining it with race non-specific (*bc-3*) or race-specific resistance recessive genes (typically $bc\text{-}2^2$). Efforts have been on-going to improve resistance against these diseases by new introductions or pyramiding resistances. Several populations have been generated, and selection is done using a variety of methods, including marker assisted selection (MAS). Last year, we reported progress made in improving resistance against *Pythium* root rot ALS and efforts to introgress BCMV and BCMNV resistances in commercial and adapted bush and climbing bean cultivars. This year we continued selection from segregating populations and lines with a focus on resistance, yield and seed types.

Materials and Methods:

i) Evaluation and advancement of backcross populations developed for *Pythium* resistance

Since 2004, selections from 20 backcross populations developed as an effort to introgress *Pythium* root rot resistance to into key commercial bean varieties have been going on. Selections are based on resistance to *Pythium* root rot and ALS using both phenotypic and genetic markers. This year, phenotypic selections were done on three F_4BCS_4 families having RWR 719 as a *Pythium* root rot resistant donor parent, i.e., F_4BCS_4 GLP 585 x RWR 719, F_4BCS_4 CAL 96 x RWR 719 and F_4BCS_4 URUGEZI x RWR 719. Five plants per selected plot were selected based on plant architecture, pod load, disease and pest resistance, early maturity and physical similarity to the recurrent parent (seed size, seed color, growth habit etc.). The selected plants were assayed for the presence of the *Pythium* root rot resistance gene using the $PYAA19_{800}$ SCAR marker.

Three hundred and eleven back cross (F_5BCS_4) lines from populations developed from AND1062, AND1055, SCAM-80CM/15 and MLB-49-89A as *Pythium* root rot resistant donors were planted and fifty plants selected per population based on phenotypic similarity (growth habit, seed size and color etc) to the recurrent parent.

ii) Marker assisted selection from families developed for combined resistance to *Pythium* and Angular leaf spot

Efforts to combine resistance genes to *Pythium* root rot and angular leaf spot (ALS) resulted in a number of combined crosses. Seventy-eight F_8 lines that were F_6 derived progenies previously selected under screenhouse condition for resistance to angular leaf spot were assayed for the presence of $PYAA19_{800}$ SCAR marker associated with *Pythium* root rot resistance gene in RWR 719 and OPE_{709} SCAR marker associated with the ALS resistance gene in MEX54.

iii) Introgressing bc-3 gene into commercial root rot resistant cultivars with I-gene through backcrossing

Commercial varieties that are resistant to *Pythium* root rots but susceptible to bean common mosaic necrosis virus (RWR 719, RWR 1946, RWR 2075) were crossed with nine bean lines, MCM 2001, MCM 5001, MCM 1015, UBR 92(25), USWK-6, TARS-VR- 7S, USCR-9, USCR-7, that have both the *I* and *bc-3* gene that confers resistance to bean common mosaic necrosis virus. F_1 populations were generated and advanced to F_2 by selfing. The rationale was to introgress the *bc-3* gene into the market class varieties and use both phenotypic selection and molecular markers to select and advance only those materials that had either *bc-3* gene alone or a combination of both genes. This past season, 50 plants from each of the 12 crosses involving UBR (92) 25, MCM 1015, MCM 2001 and MCM 5001 (a total of 600 F_2 plants) and the four susceptible parents MLB-49-89A, RWR 719, RWR 2075 and RWR 1946 were screened for the presence of the "*I*", "*bc-3*" and *Pythium* root rot resistance genes using molecular markers.

In addition a backcross program was set up for these crosses. At F_2, plants were inoculated with BCMV inoculum and resistant plants backcrossed to the respective recurrent parents. BC_1S_1 seed was planted in the field to get BCS_2 plants. Single plants selected from the F_2BCS_2 populations based on good plant architecture, seed characteristics and phenotypic background of the susceptible parents (RWR719, RWR 1946 and RWR 2075) from each population were inoculated BCMNV inoculum. Those not showing symptoms of black root (Plate 1) were assayed for resistance genes using molecular markers as described below.

Plate 1 a. F_2 Plant showing black root symptoms

Plate 1b. F_2 plant showing typical BCMV symptoms

<u>DNA Extraction:</u> Using a 2mm bore, 5 discs per leaf were cut out from 2-week old plants and placed on a Whatman plant saver card (taking precautions to prevent cross contamination) and spotted by applying gentle pressure using a pestle. The latter (saver card) were air dried at room temperature for 1 hour. Two millimeter plant saver card discs impregnated with leaf tissue were cut and each washed twice with 200µL Whatman purification reagent, incubating for 3 minutes at room temperature after each wash. The card discs were similarly washed twice with 200µL of isopropanol as described above and left to completely dry before being used as DNA template in a PCR reaction.

<u>DNA Amplification:</u> Leaf discs were used as template in a 20µL PCR premix (Bioneer Corp, Korea) containing the following: 1U *Top* DNA polymerase, 250mM dNTPs, 1.5mM $MgCl_2$, 10mM Tris-HCl (pH 9), 30mM KCl, stabilizer and tracking dye. 0.5µM of the primer and water were added to top up to the required volume. The mixture was vortexed gently and loaded in a Biorad Mycycler (BIO-RAD laboratories, Hercules, California) thermocycler. For the SW13 marker which is associated with "*I*" gene and $PYAA19_{800}$ SCAR marker associated with *Pythium* root rot resistance gene in RWR 719, the mixtures were subjected to 35 amplification cycles which consisted of: an initial denaturation step at 95^{o}C for 5 minutes and 34 cycles at 94^{o}C for 15 seconds, annealing temperature 65^{o}C for 40 seconds, extension 72^{o}C for 1 minute, a final extension of 72^{o}C for 10 minutes and a holding temperature of 4^{o}C. For ROC 11 marker associated with "*bc-3*" gene, the amplification cycles were similar except that the annealing temperature of 54^{o}C for 40 seconds. Amplicons were resolved on 1.2% agarose gel stained with 10mg ml^{-1} Ethidium bromide and the gel subsequently immersed in 0.5XTBE. Electrophoresis was performed at 70V for 1 hour and bands visualized under UV light and the image captured on a digital camera mounted on a computer.

Results and Discussion:

i) Selection of backcross (BCs) populations for resistance to *Pythium* root rot:

The RWR 719 SCAR marker identified 28 plants from three F_4BCS_4 families having the gene linked to *Pythium* root rot resistance in RWR 719 (Table 84).

Three hundred and fifty six plants were selected from 11 backcross populations based on agronomic characteristics (Table 85).

Table 84. Selection of F_4BCS_4 lines using the PYAA800 SCAR marker

Population	Selected plots	Total samples from a cross-code	Plants +ve for RWR719 marker
F_4BCS_4 GLP 585 x RWR 719	2	10	8
F_4BCS_4 CAL 96 x RWR 719	8	40	-
F_4BCS_4 URUGEZI x RWR 719	29	145	20
			28

Table 85. Phenotypic selections from 11 backcross populations developed for *Pythium* root rot resistance

Population	No. progenies per population	Plants evaluated per population	No. plants selected
F_6BCS_4 (GLP2 x MLB-49-89A)	39	50	32
F_6BCS_4 (GLP2 x SCAM80 CM/15)	49	50	36
F_6BCS_4 (GLP2 x AND 1062)	24	50	40
F_6BCS_4 (GLP585 x MLB-49-89A)	19	50	36
F_6BCS_4 (GLP585 x AND1055)	19	50	31
F_6BCS_4 (CAL96 x MLB-49-89A)	42	50	34
F_6BCS_4 (CAL96 x SACM 80 CM/15)	16	50	35
F_6BCS_4 (CAL96 x AND1055)	21	50	34
F_6BCS_4 (Urugezi x MLB-49-89A)	21	50	25
F_6BCS_4 (Urugezi x AND1055)	27	50	28
F_6BCS_4 (Urugezi x AND 1062)	31	50	25
	308	550	356

ii) Screening of combined crosses for resistance ALS and *Pythium* root rot:

The SCAR markers identified 40 lines combining PRR and ALS resistance genes (Figure 46 and Table 86). Agronomic data is being assessed to characterize the materials and make them available to national program partners.

iii) Introgressing *bc-3* gene into commercial root rot resistant cultivars with *I*-gene through backcrossing.

Locally adapted resistance sources were successfully used to transfer the *bc-3* gene into commercial root rot resistant cultivars. Although a relatively higher number of plants had the *bc-3* gene (Table 87, Figure 47), very few had a combination of *I* and *bc*-3 genes. Plants with at least *bc-3* gene (alone or in combination with "*I*" gene) have been advanced. Furthermore other results show that RWR 2075, a newly released variety in Uganda for its root rot resistance, seems to have a similar marker as that associated with resistance in RWR 719. Results are underway to confirm this observation. RWR 1946 (also newly released for its root rot resistance in Uganda) seems not to have the marker.

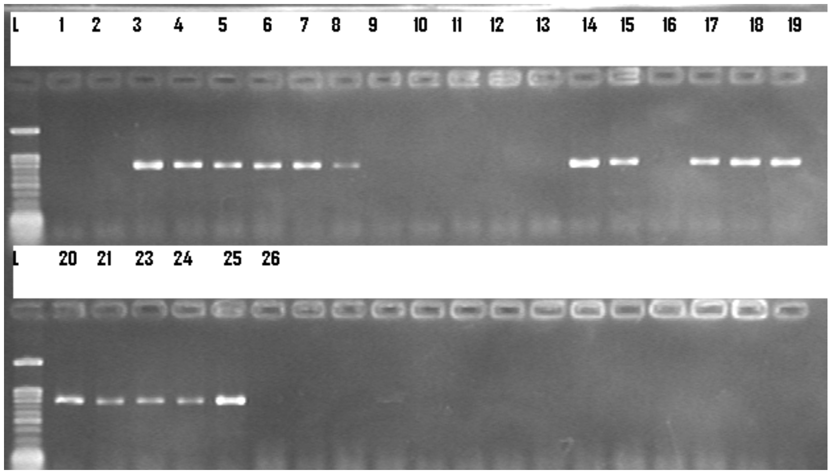

Figure 46. Screening of combined crosses for the presence of the gene conditioning resistance to *Pythium* root rots using the marker PY AA19. Left 25/100 mixed DNA ladder. Sample 3 is positive control RWR 719, and sample 26 is variety CAL 96. Absence of a band indicates absence of the gene.

Table 86. Lines with both angular leaf spot and *Pythium* resistance genes

Cross	Progenies evaluated	Plants selected/ progeny	No. plants with both PRR and ALS resistance genes
F_8 (CAL 96 x RWR 719) x (CAL 96 x MEX 54)	30	150	18
F_8 (CAL 96 x MLB-49-89A) x (CAL 96 x MEX 54)	36	180	20
F_8 (CAL 96 x SCAM 80CM /15) x (CAL 96 x MEX 54	12	60	2
Total	78	390	40

Table 87 . Plants with various combinations of genes using the SW13 and ROC11 markers.

Cross codes	No. evaluated	No. with *bc-3* gene	No. with *I* and *bc-3* genes
RWR2075 x MCM 5001	50	3	2
RWR2075 x UBR (92) 25	50	8	3
RWR 2075 x MCM 1015	50	4	2
RWR 2975 x MCM 2001	50	5	1
RWR 1946 x UBR (92) 25	50	4	1
RWR 1946 x MCM 1015	50	4	2
RWR 1946 x MCM 2001	50	3	2
RWR 1946 X MCM 5001	50	11	3
RWR 719 X MCM 1015	50	3	1
RWR 719 X MCM 2001	50	5	3
Total	**500**	**50**	**20**

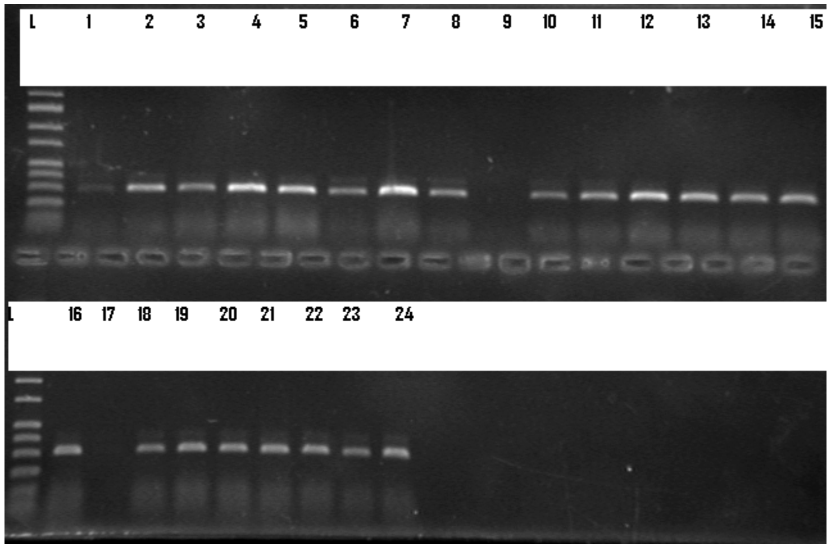

Figure 47. Screening of the cross RWR 2075 x MCM 5001 for the presence of the *bc-3* gene using the ROC 11 marker. Left 25/100 mixed DNA ladder, sample 9 is positive control MCM 5001; Sample 18 is CAB 19. Absence of a band indicates presence of the gene and vice versa.

A total of 95 plants (Table 88) were selected based on their phenotype and advanced to F_3BCS_2 where selections will be based on the presence of the *bc-3* and *I* gene using the respective molecular markers.

Table 88. Phenotypic selections on F_3BCS_2 plants

Crosses	Selected plants	No. plants with BCMV	No. plants with black root	No. plants advanced to BC-S2
RWR 719 x USWK 6	10	-	2	8
RWR 719 x TARS VR 1s	12	-	5	7
RWR 719 x TARS VR 7s		-	-	-
RWR 719 x USCR 7	10	-	7	3
RWR 719 x USCR 9	9	-	-	7
RWR 1946 x USWK 6	10	-	-	10
RWR 1946 x TARS VR 1s	10	-	-	10
RWR 1946 x TARS VR 7s	9	1	-	8
RWR 1946 x USCR 7	-	-	-	-
RWR 1946 x USCR 9	11	-	-	11
RWR 2075 x USWK 6	1	-	2	9
RWR 2075 x TARS VR 1s	7	5	-	2
RWR 2075 x TARS VR 7s	10	-	-	10
RWR 2075 x USCR 7	10	-	-	10
RWR 2075 x USCR 9	-	-	-	-
				95

iv) *Pythium* Root rot nursery

A number of lines derived from RWR 719 and identified (phenotypically and using molecular markers) to be resistant to *Pythium* root rot were incorporated into the Root Rot Nursery formed last year. This brings to 75 the number of entries in this nursery which in addition to resistance, have desirable seed and agronomic characteristics.

Contributors: R. Buruchara, C. Mukankusi, S. Sebuliba, A. Male, C. Acam, F. Mururokwere, P. Kimani, (CIAT); G. Mukeshimana, A. Namayanja, and G. Tusiime

Collaborators: S. Beebe and M. Blair

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Activity 2.4 Yield potential: climbing beans

Highlights

- QTL for growth habit and climbing ability were identified on six chromosomes, although many were located on B04. This illustrates the complexity of growth habit, and implicitly, of crop domestication as growth habit was reduced from climbing to bush type.

2.4.1 Detection of QTL for climbing ability and component traits in common bean

Rationale: Common bean varies in growth habit from aggressive climbing types to bush beans. While most production of common beans worldwide has been with bush beans, the highest yields are obtained with climbing types, which under favorable growing conditions, can produce as much as 4,500 kg ha^{-1}. One inherent characteristic of climbing beans is their capacity to climb, which is closely related to growth habit. Growth habit is determined by a combination of factors including determinate versus indeterminate growth, total plant height, degree of branching and internode length. Together these factors make up climbing ability. The objective of this research was to determine the quantitative trait loci (QTL) controlling climbing ability in a $F_{5:8}$ recombinant inbred line population derived from an inter-gene pool cross of an aggressive indeterminate climbing bean with type IV growth habit (G2333) by an indeterminate bush bean of type IIb growth habit (G19839).

Materials and Methods:

Plant materials: A total of 84 $F_{5:8}$ recombinant inbred lines (RILs) were developed from the cross G2333 x G19839 by single-seed descent where G2333 is from Mexico and possesses type IVa growth habit, while G19839 is from Peru and possesses type IIb growth. Both are somewhat tolerant of low phosphorus and have been used to study phosphorus use efficiency.

Planting sites: The population was planted in four experiments across environments that varied in altitude (from 1000 to 1750 masl) and soil fertility (low versus high phosphorus) over three sites: Darién (1,485 masl), Palmira (965 masl), both in the department of Valle de Cauca while a final experiment was in Popayán (1,730 masl). In Darién, the two trials were planted under conditions of high (64.3 ppm) and low phosphorus (1.7 ppm), respectively. Agronomic management was the same for the four trials, except for fertilizer applications for the low-phosphorus trial in Darién, where, to maintain the low phosphorus levels, only 7.5 kg ha^{-1} of phosphorus in the form of triple super-phosphate was applied. The other trials received high phosphorus treatment of 45 kg ha^{-1}.

Experimental design: At each of the four sites, an experimental design of randomized complete blocks was established, with 86 treatments and 2 replications. The size of the plot or experimental unit was one row, 3 m long, in which 30 seeds were sown at 10-cm intervals each, with a distance of 1.2 m between rows. Field data were collected for climbing ability, plant height, internode length and branch number. Climbing ability (CA) was measured according to a visual scale that ranged from 1 to 9, where 1 corresponded to the highest and most aggressive plants and 9 to the smallest and least aggressive plants. Two evaluations were made, one at 45 days and the second 75 days after planting for both climbing ability and plant height.

Results and Discussion: QTL were identified by composite interval mapping for plant height, internode length and number of branches per plant on a genetic map covering all common bean linkage groups with a total length of 1175 cM. A total of 7 QTL were found for plant height, 9 for climbing ability, 6 for internode length and 1 for branch number (Table 89). LR values ranged from 14.8 to 25.3.

QTL number varied per location with the favorable environmental conditions in Darién HP and Popayán producing a higher proportion of significant marker association (with 7 and 9 QTL, respectively) than the less favorable environments of Palmira and Darién LP (with 6 and 1, respectively).

Table 89. QTL for plant height (PH), internode length (IL), climbing ability (CA) and branch number (BN) in the G2333 x G19839 RIL population detected at either 45 or 75 days after planting in four field experiments (Darién under high phosphorus (HP) or low phosphorus (LP), Popayán (Pop) and Palmira (Pal).

Trait - Evaluation	Site	QTL name	Linkage group	Closest marker	LR	R^2	Total R^2	Additivity
PH-1	HP	*Plh1-2*	B04	X010.85	22.82	0.1952	0.4812	0.1903
PH-1	Pop	*Plh1-1*	B03	BM189	15.11	0.1399	0.5119	0.1358
PH-1	Pop	*Plh1-3*	B04	PV-ctt001	16.14	0.1403	0.5276	0.1395
PH-1	Pop	*Plh1-4*	B08	M130.7	15.41	0.1055	0.4762	0.1233
PH-2	HP	*Plh2-1*	B04	PV-ctt001	20.53	0.2489	0.4158	0.2523
PH-2	LP	*Plh2-3*	B11	BMd033	15.35	0.1637	0.3039	0.1887
PH-2	Pal	*Plh2-2*	B04	BMd026	16.90	0.1445	0.4624	0.1255
IL	HP	*Int2*	B04	X010.85	23.69	0.1839	0.5407	1.8164
IL	HP	*Int3*	B04	PV-ctt001	15.97	0.2033	0.453	1.9515
IL	Pal	*Int4*	B04	L040.75	22.52	0.2836	0.4067	1.1886
IL	Pal	*Int2*	B04	BMd026	19.95	0.1910	0.3141	0.9671
IL	Pal	*Int3*	B04	PV-ctt001	19.48	0.1574	0.474	0.8533
IL	Pop	*Int1*	B03	Q170.46	19.72	0.1609	0.3926	1.1631
CA-1	HP	*Cab1-1*	B04	PV-ctt001	20.74	0.2026	0.4946	-0.5859
CA-1	HP	*Cab1-4*	B07	BM046	18.84	0.1872	0.4884	0.5846
CA-1	Pal	*Cab1-2*	B04	BMd026	19.19	0.1759	0.4234	-0.3575
CA-1	Pop	*Cab1-1*	B04	PV-ctt001	16.36	0.1353	0.5432	-0.3522
CA-1	Pop	*Cab1-3*	B05	F081.0	14.81	0.1152	0.4093	-0.3356
CA-1	Pop	*Cab1-5*	B10	W060.6	15.53	0.1381	0.4279	-0.3833
CA-1	Pop	*Cab1-6*	B11	BMd033	14.79	0.2161	0.5161	-0.4408
CA-2	HP	*Cab2-1*	B04	PV-ctt001	22.01	0.2373	0.4771	-0.5622
CA-2	Pal	*Cab2-1*	B04	PV-ctt001	23.54	0.2542	0.4313	-0.6004
BN	Pop	*Brn1*	B04	BM161	25.34	0.2235	0.5321	0.6890

In addition more QTL were observed at the earlier evaluation stage of 45 DAP compared to the later evaluation stage of 75 DAP for both plant height (4 versus 3 QTL) and climbing ability (7 versus 2 QTL). The largest number and most significant QTL were found on the lower half of linkage group B04 suggesting a major pleiotropic locus for growth habit traits at this location of the genome that is distinct from previously characterized genes which control plant morphology of the crop.

Contributors: M.W. Blair (SBA-1, CIAT), O.E. Checa (Univ. Nariño)

Collaborators: I. Ochoa (CORPOICA), S. Beebe (CIAT)

Activity 2.5 Characterizing and monitoring pathogen and insect diversity

Highlights:

- Sixteen *Pythium* species were found to be associated with beans root rots in Rwanda and the cultivars CAL 96, RWR 617-97A, Urugezi and RWR 1668 were susceptible to all these species. G2331, AND 1062, MLB-40-89A, Vuninkingi, AND 1064 and RWR 719 were resistant.

2.5.1 Monitoring of whitefly populations in the Andean zone

Rationale: Monitoring the changes that could occur in white fly populations and the composition of species in the target areas of the Andean Zone, where bean and snap bean crops are important, is one of the main objectives of the Project financed by the Regional Fund of Agricultural Technology (FONTAGRO). In addition, the Project financed by the Ministry of Agriculture and Rural Development (MADR), also has as important goal to periodically sample whitefly species on hot and sweet peppers in the Cauca Valley, in order to measure resistance to insecticides. Since the same species of white fly pass between bean and peppers, this activity is relevant for the bean program. This information is necessary to modify the existing management systems and to be prepared for new situations in the future.

Materials and Methods: In 2008 a total of 20 white fly samples (adults and pupae) were processed. These were collected in 8 locations of the Antioquia, Cundinamarca and Tolima departments of Colombia, at altitudes ranging between 1730 and 2465 meters above sea level (masl). Samples were taken from beans and snap beans within the project financed by FONTAGRO. For the MADR project, a total of 12 whitefly samples (adults and pupae) were processed, having been collected in 4 locations of the Cauca Valley Department of Colombia, at altitudes ranging between 941 and 1437 meters above sea level (masl). Samples were taken from both hot pepper and sweet peppers. RAPD techniques (primer OPA-04) were used to identify species of pupae and adults. The identification was based on morphological characteristics of pupae and comparisons between RAPD patterns in samples brought from the field with those of existing mass-rearing colonies maintained at CIAT.

Results and Discussion: The analysis of 20 samples taken in 8 locations in the Antioquia, Cundinamarca and Tolima departments of Colombia (Figure 48), showed that 100 % of the whiteflies collected belong to *Trialeurodes vaporariorum,* identified as the most important whitefly species on bean and snap beans crops in the hillside areas of Antioquia, Cundinamarca and Tolima.

In order to determine the distribution of the whitefly in sweet pepper, other areas in Colombia continue to be monitored, where it is considered to be an important pest. Four areas located in the northern and central part of the Valle de Cauca department were sampled, with altitudes ranging between 941 and 1437 masl. As an example of the RAPD patterns obtained, Figure 49 shows that 17% of the collected samples were of *T. vaporariorum* and the other 83 %, found between 900 and 1400 masl, correspond to *B. tabaci* biotype B. Presence of biotype B of *B. tabaci* was evidenced in the field by proofs of physiological disorders (irregular ripening) and by morphological differentiations with *T. vaporariorum*. These identifications were confirmed by the means of RAPD type molecular trials. Since *Bemisia* spp. are vectors of Gemini viruses of Phaseolus, these results are directly relevant to common bean.

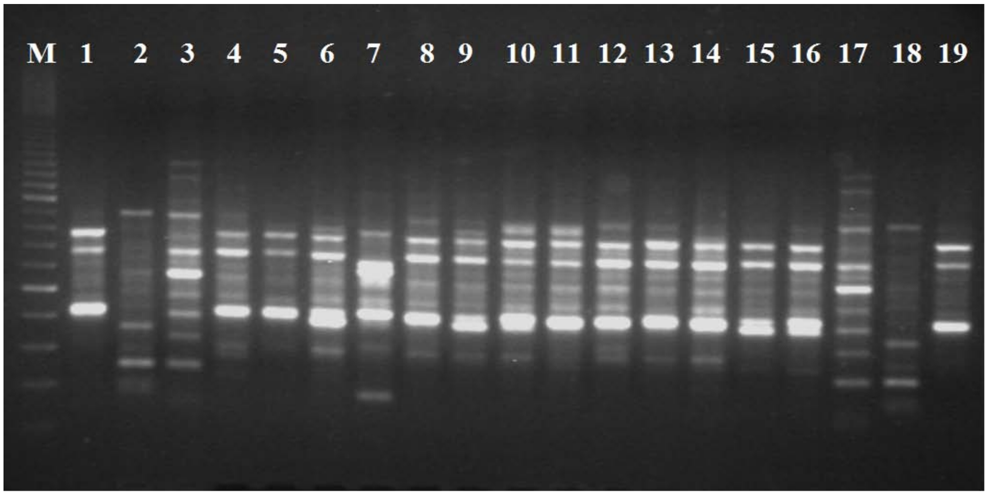

Figure 48. RAPD's of white flies collected in Antioquia and Cundinamarca (Colombia) in common bean and snap bean. Amplification of the primer OPA-04: M, Marker 100 pb; 1, *T. vaporariorum* CIAT; 2, *B. tabaci* biotype A CIAT; 3, *B. tabaci* biotype B CIAT; 4-5, adults of *T. vaporariorum* collected in Aguasclaras (Carmen de Viboral, Antioquia, 2165 masl); 6, pupae (not determined) collected in La Aurora (C. de Viboral, Ant. 2189 masl); 7, pupae de *T. vaporariorum* collected in La Aurora (Carmen de Viboral, Antioquia. 2189 masl); 8-9, adults of *T. vaporariorum* collected in La Aldana (Carmen de Viboral, Antioquia, 2169 masl); 10-11, adults de *T. vaporariorum* collected in San Juan Bosco (Marinilla, Antioquia, 2200 masl); 12-13, adults of *T. vaporariorum* collected in La Floresta (Santuario, Antioquia, 2134 masl), 14-15, adults of *T. vaporariorum* collected in Laderas (Fómeque, Cundinamarca, 1982 masl); 16, adults of *T. vaporariorum* collected in La Unión (Fómeque, Cundinamarca, 1730 masl); 17, *B. tabaci* biotype B CIAT; 18, *B. tabaci* biotype A CIAT; 19, *T. vaporariorum* CIAT.

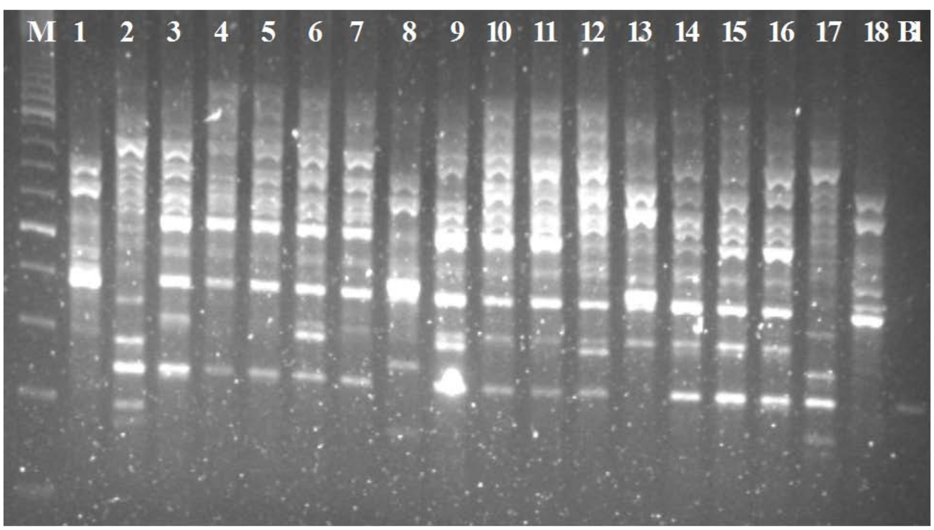

Figure 49. RAPD's of white flies collected in the northern and central Cauca Valley in hot pepper. Amplification ofthe primer OPA-04: M, Marker 100pb; 1, *T. vaporariorum* CIAT; 2, *B. tabaci* biotype A CIAT; 3, *B. tabaci* biotype B CIAT; 4-5, adults of *B. tabaci* biotype B collected in La Unión (941 masl), 6-7, adults of *B. tabaci* biotype B collected in La Cumbre (1437 masl); 8, pupae of *T. vaporariorum* collected in La Cumbre (1437 masl); 9, pupae of *B. tabaci* biotype B collected in La Cumbre (1437 masl); 10-11, adults of *B. tabaci* biotype B collected in La Cumbre (1398 masl); 12, adults of *B. tabaci* biotype B collected in Restrepo (1181 masl); 13, adults of *T. vaporariorum* collected in Restrepo (1182 masl); 14-15, pupae of *B. tabaci* biotype B collected in Restrepo (1181 masl); 16, *B. tabaci* biotype B CIAT; 17, *B. tabaci* biotype A CIAT; 18, *T. vaporariorum* CIAT; Bl, Reaction blank.

2.5.2 Diversity, distribution and pathogenicity of *Pythium* species in Rwanda

Rationale: Beans (*P. vulgaris* L.) is a major source of protein in Eastern Africa and particularly in Rwanda. Produced under low input agriculture, beans are vulnerable to attack by diseases and other constraints. One of these diseases is *Pythium* root rots. The increase in severity and incidence of root rots have been associated with a relatively recent evolution of farming systems especially under high demographic pressure and the resulting decline in soil fertility (Rusuku et al., 1997). This is typical of Rwanda where the importance of root rots was recognized as far back as late 80s (CIAT, 1992). There are efforts in Rwanda to routinely incorporate resistance to *Pythium* root rots in improved bush and climbing beans varieties. However, as this is done, it is considered important to determine and monitor the variation, distribution and pathogenicity of *Pythium* species in Rwanda. The information will then be used to identify or verify sources of resistance and for phenotypic evaluations in varietal improvements. The aim of this study was to characterization *Pythium* species responsible for bean root rot in Rwanda.

Materials and Methods: Soil and plant samples were collected from fields in 24 districts of Rwanda (Table 90) at predetermined positions and at different altitude levels [low (900 – 1400 m), medium (1400 – 1650 m) and high (1650 – 2300 m)]. At each field, information was taken on the physical location including: Province, District and Sector; GPS location. Attributes of the beans varieties in the fields were observed and noted, e.g. type of growth; as well as on the cropping systems.

Table 90. Distribution of the samples by district in Rwanda

	Number of samples	**Altitude**
Huye	14	MA
Gisagara	14	MA
Nyanza	26	MA
Karongi	27	MA
Muhanga	4	MA
Ruhango	8	MA
Nyamasheke	12	MA
Rusizi	18	LA
Nyamagabe	5	MA
Bugesera	5	LA
Gasabo	6	MA
Rwamagana	6	LA
Kayonza	10	LA
Ngoma	12	MA
Kirehe	5	MA
Gatsibo	4	MA
Nyagatare	19	LA
Rurindo	5	HA
Gicumbi	14	HA
Nyarugenge	6	MA
Gakenke	1	HA
Nyabihu	5	HA
Rubavu	3	HA
Musanze	2	HA
Total of samples	**231**	

LA: Low altitude, MA: Middle altitude, HA: High altitude.

Isolation and purification of *Pythium* species: Initial steps of isolation were done at ISAR's laboratories at Rubona and Ruhengeri in Rwanda. Follow-up laboratory and screenhouse activities were carried out at Kawanda Agricultural Research Laboratories. Isolation of *Pythium spp.* from plant tissues was done as described by White (1988). Infected root pieces from the field samples (approximately 0.5- 2 cm long) were cut from expanding lesions and plated onto the selective medium of cornmeal agar (CMA) amended with 2ml/l and 3ml/l of antibiotics pimaricin and rifamycin respectively, to stop bacterial growth. Cultures were incubated at 20°C for 2-5 days. Hyphal tip method was used to sub-culture and transfer mycelia onto potato dextrose agar (PDA) slants.

Molecular characterization of *Pythium* spp: DNA was extracted from harvested mycelia according to the procedure described by Mahuku (2004). Mycelia were ground to a fine paste in a mortar containing TES extraction buffer (0.2 M Tris-HCl [pH 8], 10 mM EDTA [pH 8], 0.5 M NaCl, 1% SDS) and sterilized acid-washed sea sand. Additional TES buffer containing Proteinase K was added and the mixture incubated at 65ºC for 30 min. DNA was precipitated using ice-cold isopropanol and the pellet was washed twice with 70% ethanol, dried and dissolved in TE buffer (10 mM Tris-HCl [pH 8], 1 mM EDTA). PCR analysis was performed using Oomycete ITS (Internal Transcribed Sequence) region primers to differentiate *Pythium* from other closely related fungi (White et al., 1990). The PCR reaction was performed in 50µl-reaction volumes containing 5µl of 10X PCR buffer, 8µl of 25mM $MgCl_2$, 2.5 µl of 1.25mM dNTP, 0.2 µl of each primer (20µM) 18S (5'-TCC GTA GGT GAA CCT GCG G-3') and 28S (5'-TCC TCC GCT TAT TGA TAT GC-3'), 20 ng of DNA, and 0.2µl Taq DNA polymerase (5U/µl). Amplification was performed in a BIORAD Mycycler Thermocycler programmed for initial denaturation at 94°C for 5 min, for 35 cycles at 94ºC for 1 min, annealing at 68°C for 1 min, and extension at 72°C for 1.5 min, followed by a final extension for 7 min at 72°C. The products were run on 2% agarose gels containing 5mg ml^{-1} of ethidium bromide at a voltage of 100V for 2 hours and visualized under UV light.

rDNA sequence analysis. Residual primers and dNTPS in the PCR products were removed using QIAquick™ PCR purification spin columns following the manufacturer's protocol (QIAGEN, Crawley, 1997). Direct sequencing of the PCR amplified products was carried out using ITS 2 primers (White et al., 1990). Sequences from ITS 1 region of the ribosomal gene were edited using the Editseq program (DNASTAR Inc., Madison, Wis). The ITS1 sequences of the test isolates were compared with ITS 1 sequences of known *Pythium* species available in the public databases using Seqman program (DNASTAR). Multiple alignment of the sequenced product of ITS 1 was performed for comparison.

Pathogenicity of *Pythium* species: The pathogenicity of the characterized *Pythium spp* was evaluated on the susceptible bean cultivars CAL 96 and "Urugezi", using 2 or 3 isolates of each species. Similar evaluations were carried out on a few Rwandan varieties (G2331, R617-97A, RWR 1668, Vuninkingi) and other sources of resistance (RWR 719 MLB-40-89A AND 1064 and AND 1062) in the screenhouse. Seed of these cultivars were planted in wooden trays each infested with a distinct *Pythium* species. The trial was set up in a completely randomized block design (CRBD). Three weeks after emergence, the surviving plants were uprooted, washed and severity of root rots assessed using the CIAT scale of 1-9 (Abawi and Pastor Corrales, 1990). Isolates that had a mean disease score of 1-2, were considered non pathogenic; those with a score of 3-5 were considered mildly pathogenic and those that gave a score of 6-9 were highly pathogenic.

Results

Distribution of *Pythium* spp: Results of this study showed that, *P. vexans* was the most widespread species (23 isolates), followed by *P. indigoferae* (9 isolates); *P. rostratifingens* (6 isolates), *P. torulosum* (5 isolates), *P. ultimum* and *P spinosum* (4 isolates each) (Table 91).

Table 91. Distribution of the *Pythium* species by district in Rwanda

District	*P. indigoferae*	*P. chamaehyphon*	*P. torulosum*	*P. cucurbitacearum*	*P. diclinum*	*P. conidiophorum*	*P. arrhenomanes*	*P. pachycaule*	*P. ultimum*	*P. vexans*	*P. folliculosum*	*P. macrosporum*	*P. rostratifingens*	*P. spinosum*	*P. dissotocum*	*P. rostratum*	*Total*
Huye	-	-	2	-	-	-	-	-	-	-	-	1	-	1	-	1	5
Gisagara	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Nyanza	2	-	1	-	-	-	-	-	-	3	1	-	-	-	-	-	7
Karongi	1	-	-	-	-	-	-	-	1	1	1	-	-	-	1	-	5
Muhanga	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	2
Ruhango	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Nyamasheke	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	2
Rusizi	-	-	-	-	-	-	1	-	-	-	-	-	2	2	1	-	6
Nyamagabe	1	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-	4
Bugesera	-	-	-	-	-	-	-	-	1	3	1	-	-	-	-	-	5
Gasabo	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	4
Rwamagana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Kayonza	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	2
Ngoma	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2
Kirehe	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Gatsibo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Ngoma	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Nyagatare	1	-	-	-	-	1	-	-	1	2	-	-	-	-	-	-	5
Rurindo	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	2
Gicumbi	-	1	-	1	1	-	-	-	-	1	-	-	-	-	-	-	4
Nyarugenge	-	-	1	-	-	-	-	-	1	3	-	-	-	-	-	-	5
Gakenke	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Nyabihu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Rubavu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Musanze	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Total	**9**	**2**	**5**	**1**	**3**	**3**	**1**	**1**	**4**	**23**	**3**	**1**	**6**	**4**	**3**	**1**	**70**

Molecular characterization: A total, of 231 isolates were collected. However, 96 representing different regions were sequenced. ITS sequences were compared using Blast searches with sequences deposited at the National Center for Biotechnology Information (NCBI). Identity of species with sequences having less than 100% similarity to published sequences in GenBank were further analysed using phylogenetic analysis using parsimony (PAUP) version 4·0b (Swofford, 2001). The criterion for the selection of closely related species was based on clades of *Pythium* spp. generated by Lévesque and de Cock (2004). As a result a total of 16 different *Pythium* species were identified (Table 91). These were *P. indigoferae, P. chamaehyphon, P. torulosum, P. cucurbitacearum, P. diclinum, P. conidiophorum, P. arrhenomanes, P. pachycaule, P. ultimum, P. vexans, P. folliculosum, P. macrosporum, P. spinosum, P. rostratifingens, P. dissotocum* and *P. rostratum.*

Pathogenecity: All the *Pythium* species identified were pathogenic to the susceptible varieties [CAL 96 (Plate 2) and URUGEZI] and other varieties (RWR 617-97A and RWR 1668) evaluated (Table 92). Bean cultivars G2331, AND 1062, MLB-40-89A, Vuninkingi, AND 1064 and RWR 719 (Plate 3) gave resistant reactions. The study confirmed previous reports regarding resistance of some of the known sources of resistance and the value of this resistance (Otsyula et al., 1998; Buruchara et al., 1999; Buruchara and Kimani 2001, Buruchara et al., 2007, Gichuru et al., 2008). It was however interesting that the known susceptible varieties were affected by all the species identified indicating the potential impact of *Pythium* species under favorable disease conditions.

Plate 2: Roots of the susceptible (CAL 96) bean variety to the *Pythium* spp.

Plate3: Roots from resistant variety (RWR 719) to the *Pythium* spp..

Table 92. Pathogenicity and disease severity following artificial inoculation by different *Pythium* species on bean varieties cultivated in Rwanda.

Beans Varieties	***Pythium* species severity1**															
	P. arrheno manes	*P. chamae Hyphon*	*P. conidio Phorum*	*P. cucurbita Cearum*	*P. diclinum*	*P. disso tocum*	*P. follicu losum*	*P. indigo Ferae*	*P. pachy caule*	*P. rostrati fingens*	*P. spinosum*	*P. torulosum*	*P. ultimum*	*P. vexans*	*P. macrospor um*	*P. rostratum*
CAL 96	8.5AB	8.1A	8.3A	8.8A	8.3B	8.4A	8.0B	7.8B	7.1B	8.4A	8.7A	8.2A	8.4A	8.4A	8.2B	8.6A
G2331	3.9D	2.1 DC	2.4B	2.0DE	1.7DC	1.6ED	2.1DC	2.0C	1.8ED	1.4DC	1.6E	2.0D	1.7C	2.0ED	2.8E	1.6DC
RWR 617-97A	7.9BC	8.4A	8.0A	7.2C	8.3B	7.9B	7.8B	7.7B	8.2A	7.3B	6.0C	7.4B	7.3B	7.7B	6.8D	6.2B
URUGEZI	8.7A	8.0A	8.3A	8.7A	8.7A	8.5A	8.5A	8.3A	8.2A	8.7A	8.7A	8.5A	8.8A	8.8A	9.0A	8.5A
RWR 1668	7.7C	6.1B	7.7A	7.8B	8.3B	5.8C	8.2BA	7.4B	6.3C	8.5A	8.2B	8.1A	8.6A	6.0C	7.4C	6.5B
AND 1062	2.0E	1.9CD	1.9BC	2.2D	1.4DE	1.5ED	1.7DE	1.5DCE	1.8ED	1.2DC	1.6E	1.8D	1.5DC	1.9ED	2.0FG	1.6DC
MLB 40-89A	2.3E	1.6DE	1.7CD	2.1DE	1.3DE	1.5ED	1.6E	1.5DE	2.1D	1.3DC	1.4EF	1.7ED	1.6DC	1.8E	1.9G	1.9DC
VUNINKINGI	1.8E	1.4E	1.2D	1.7E	1.2E	1.2ED	1.1F	1.2E	1.5E	1.1D	1.1F	1.3E	1.3D	1.2F	2.0FG	1.3D
AND 1064	2.2E	2.2C	2.0BC	2.1DE	1.9C	1.9D	2.2C	1.9DC	2.3D	1.5C	2.0D	2.6C	1.9C	2.4D	2.5FE	2.1C
RWR 719	2.2E	1.6DE	1.6CD	2.0DE	1.5DE	1.7D	1.5FE	1.4E	1.9ED	1.2DC	1.8ED	1.6ED	1.2D	1.6EF	1.9G	1.4D
SE	0.25	0.16	0.22	0.17	0.13	0.17	0.18	0.18	0.20	0.13	0.13	0.17	0.16	0.18	0.19	0.21
F(9,288)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

1: Based on CIAT scale of 1 to 9

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Contributors: Nzungize R. J[1]., Buah S[2]. , Mukankusi[2] C., Buruchara[2] R., Baudoin J.P[3].
[1]= ISAR, [2] = CIAT- Africa [3] = Gembloux Agricultural University, Belgium

Activity 2.6 Developing integrated disease and pest management components

Highlights:

- All of the bean-planted areas in Colombia and Ecuador included in the Fontagro-financed project "Reduction in the Use of Pesticides and Development of Resistance in Rice and Common Bean Crops in Colombia, Venezuela and Ecuador" were monitored for white fly populations.
- Whitefly species and biotypes, thrips and leafminers were identified, patterns of pesticide use for whitefly, thrips and leafminers registered, and levels of pesticide resistance in whitefly, thrips, and leafminer populations in Colombia quantified.
- *Psuedomonas sp* were isolated and shown to have antagonistic effects on *Pythium spp*
- Genetic diversity of varietal mixtures from southwest Uganda was characterized with indications of its potential value in the region.

2.6.1 Reduction of pesticide use in common bean and snap bean crops through the development and implementation of IPM strategies in Colombia and Ecuador: on-farm surveys and baseline studies of pest resistance

Rationale: As indicated in the 2007 Annual Report, monitoring of insecticide resistance levels in adults and immature populations of whiteflies, thrips and leafminers is a major objective of the Fontagro-financed project. The two main whitefly species, thrips and leafminers in the Andean zone are a target of excessive use of insecticides. This is reflected in ever increasing levels of resistance to insecticide and difficulties in control. The principal purpose of a continuous monitoring of insecticide resistance is to develop alternative management strategies that will help to overcome resistance or delay the onset of this phenomenon.

Materials and Methods: The main areas sampled were the northern part of Ecuador, and Valle de Cauca, Antioquia, Cundinamarca and Tolima departments in Colombia. Tests for insecticide resistance measurements were carried out in 43 different sites: 30 in Colombia and 13 in Ecuador, at altitudes ranging between 940 and 2465 masl. Using previously established diagnostic dosages for nymphs and adults, populations were tested in target areas. Adult resistance levels were monitored under field conditions by means of the insecticide-coated glass vial technique. Resistance of immature stages was tested by using the foliage dipping technique. Systemic novel insecticides (mostly neonicotinoids) were tested using the petri dish technique.

Results and Discussion:

Trialeurodes vaporariorum

Valle de Cauca and Antioquia regions: Important changes were detected in adults of *T. vaporariorum.* High levels of resistance to organophosphates (methamydophos) were registered in most of the evaluated sites. Intermediate levels of resistance were registered to pyrethroid (cypermethrin) in Antioquia. All the races showed susceptibility to diagnostic dosages of carbamates (methomyl), neonicotinoids (imidacloprid) and the neirextoxine (thioxiclam hydrogen oxalate) (Table 93).

Table 93. Response (percentage mortality) of *Trialeurodes vaporariorum* adults to five insecticides in 10 areas of the Valle de Cauca – Antioquia regions of Colombia. Diagnostic dosages in µg vial^{-1} were tested using insecticide-coated glass vials, Diagnostic dosages in µg vial^{-1} or ppm.

Site (Department)[a]	methomyl (2.5 µg vial^{-1})	methamidophos (32 µg vial^{-1})	cypermethrin (500 µg vial^{-1})	imidacloprid (40 ppm)	thioxiclam hydrogen oxalate (1500 ppm)
CIAT	100.0 a[b]	93.8 a	89.7 ab	88.2 bcd	87.2 cde
Pradera 2 (V)	100.0 a	8.5 f	75.7 abcde	89.1 bcd	94.6 abcd
La Cumbre (V)	100.0 a	42.1 cd	86.3 abc	84.2 cd	97.0 ab
C.Viboral 1 (A)	100.0 a	21.7 de	66.3 bcde	91.8 bc	91.8 bcde
C.Viboral 2 (A)	100.0 a	22.0 ef	62.6 de	92.9 bc	85.9 de
Santuario 1 (A)	100.0 a	53.0 bc	53.7 e	98.0 a	89.0 cde
Marinilla (A)	100.0 a	36.8 cde	63.2 cde	99.0 a	91.0 cde
Santuario 2 (A)	100.0 a	58.1 bc	79.9 abcd	95.9 ab	97.9 a
El Cerrito (V)	97.9 b	46.9 bc	88.8 a	91.6 bcd	81.1 e
Pradera1 (V)	94.9 c	63.8 b	85.1 abc	84.9 cd	93.7 abc
Tulua (V)	93.8 c	38.1 cde	93.8 a	82.3 d	92.6 abc

[a] Departments (A)=Antioquia, (V)= Valle de Cauca; [b] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ using LSD test.

Figure 50 presents results of periodic measurements (1997-2008) of resistance to methamidophos in *T. vaporariorum* adult populations collected in three zones of Valle de Cauca and one in Antioquia. A significant decrease in resistance levels was detected in Pradera and El Cerrito in the Cauca Valley. Increases in resistance levels were found in La Cumbre (Valle) and in Carmen de Viboral (Antioquia).

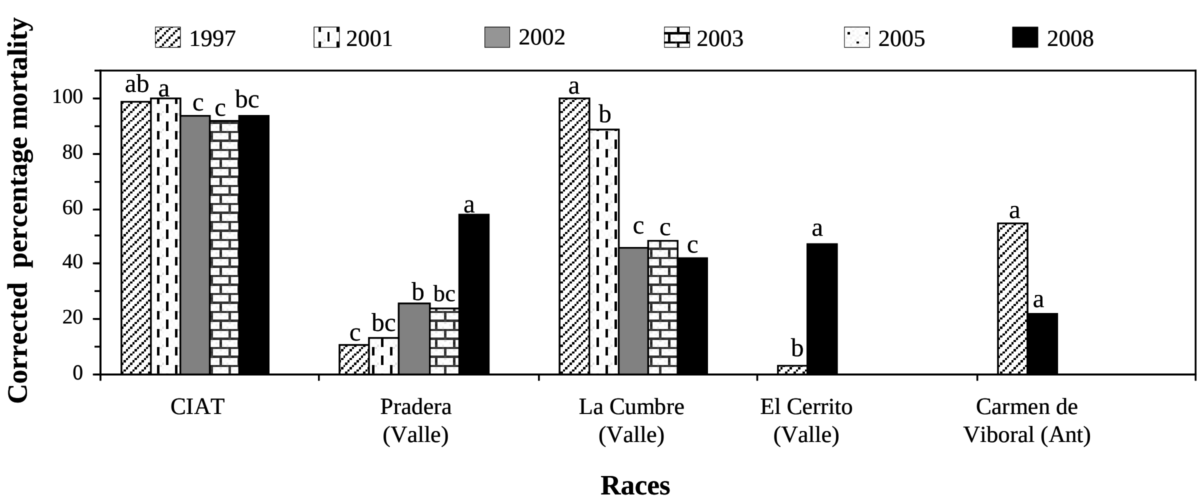

Figure 50. Changes in toxicological responses to methamidophos (32 µg vial^{-1}) in adult populations of *Trialeurodes vaporariorum*. Columns labeled with the same letter are not significantly different ($P = 0.05$) using the LSD test. Each site analyzed separately. CIAT = reference strains.

A reduced response to the growth regulator buprofezin was detected in first instar nymphs of *T. vaporariorum* collected in El Cerrito and Pradera in Valle de Cauca. The Pradera strain exhibited intermediate levels of resistance to the neonicotinoid imidacloprid (Table 94).

Table 94. Response (percentage mortality) of *Trialeurodes vaporariorum* nymphs to three insecticides in Valle de Cauca and Antioquia Departments of Colombia. Diagnostic dosages in ppm.

Site (Department)[a]	buprofezin (16 ppm)	diafenthiuron (300 ppm)	imidacloprid (300 ppm)
C.Viboral 1 (A)	100.0 a[b]	100.0 a	99.5 a
Santuario 2 (A)	100.0 a	100.0 a	99.4 ab
CIAT	100.0 a	100.0 a	100.0 a
C.Viboral 2 (A)	100.0 a	97.6 b	82.3 cd
La Cumbre (V)	100.0 a	100.0 a	97.9 ab
Santuario 1 (A)	100.0 a	100.0 a	90.3 cd
Marinilla (A)	100.0 a	100.0 a	97.6 ab
Tulua (V)	98.4 a	100.0 a	88.9 c
El Cerrito (V)	52.2 b	100.0 a	100.0 a
Pradera 2 (V)	35.0 c	100.0 a	76.4 d
Pradera 1 (V)	29.0 c	100.0 a	91.8 bc

[a] Departments (A)=Antioquia, (V)= Cauca Valley; [b] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ by LSD test.

Periodic resistance measurements were also made on nymphal populations of *T. vaporariorum* collected in Pradera and El Cerrito (Valle de Cauca). A significant increase in the level of resistance to buprofezin was detected in Pradera and El Cerrito, possibly due to excessive use of this insecticide in those areas of Valle de Cauca in Colombia (Figure 51).

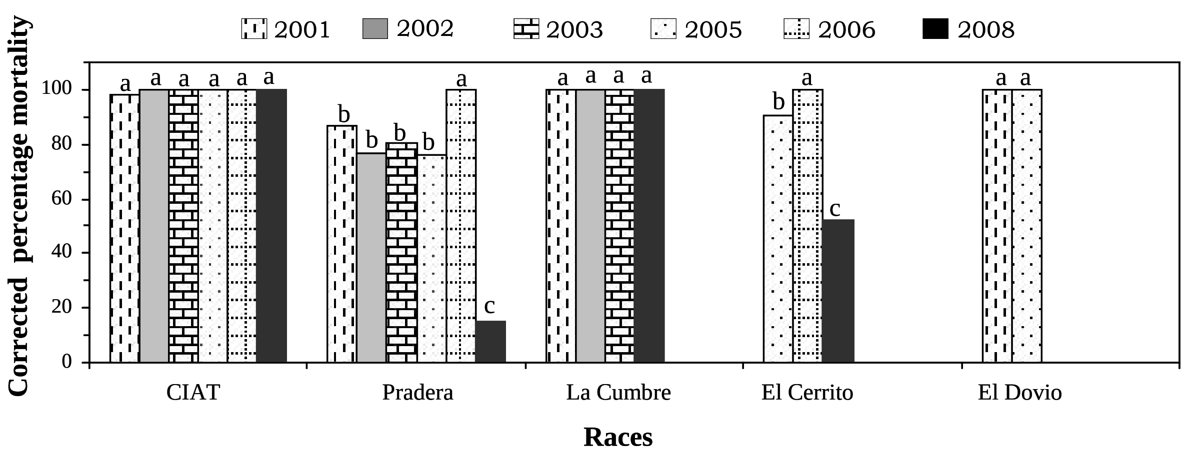

Figure 51. Changes in toxicological responses to buprofezin (16 ppm) in nymphal populations of *Trialeurodes vaporariorum*. Columns labeled with the same letter are not significantly different ($P = 0.05$) using the LSD test. Each site analyzed separately. CIAT = reference strains.

Cundinamarca-Tolima region: In this region greater changes were detected. In general, the response (mortality) of *T. vaporariorum* adults to methamidophos was low (Table 95); however, nymphs are still susceptible to the insecticides that were tested (Table 96).

Table 95. Response (percentage mortality) of *Trialeurodes vaporariorum* adults to five insecticides in the Cundinamarca and Tolima regions of Colombia. Diagnostic dosages in µg vial^{-1} were tested using insecticide-coated glass vials, Diagnostic dosages in µg vial^{-1} or ppm.

Site (Department)[a]	methomyl (2.5 µg vial^{-1})	methamidophos (32 µg vial^{-1})	cypermethrin (500 µg vial^{-1})	imidacloprid (40 ppm)	thiocyclam hydrogen oxalate (1500 ppm)
CIAT	100.0 a[b]	93.8 a	89.7 a	88.2 bc	87.2 b
Cajamarca 1 (T)	100.0 a	43.2 b	82.1 ab	89.7 ab	77.3 b
Cajamarca 2 (T)	100.0 a	12.9 b	83.9 ab	95.7 a	78.5 b
Pasca (C)	100.0 a	31.2 b	81.7 a	85.4 bc	99.0 a
Fómeque 2 (C)	100.0 a	27.0 b	57.9 c	86.2 bc	95.7 a
Fómeque1 (C)	97.9 a	26.6 b	69.1 bc	81.7 c	95.7 a

[a] Departments (C) = Cundinamarca, (T) = Tolima; [b] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ level by LSD.

Table 96. Response (percentage mortality) of *Trialeurodes vaporariorum* nymphs to three insecticides in the Cundinamarca and Tolima regions of Colombia, using diagnostic dosages in ppm. Tests were done following the methodology suggested by Prabhaker et al. (1985)[a].

Place (Department)[b]	buprofezin (16 ppm)	diafenthiuron (300 ppm)	imidacloprid (300 ppm)
Cajamarca 1 (T)	100.0 a[c]	100.0 a	100.0 a
CIAT	100.0 a	100.0 a	100.0 a
Fómeque 2 (C)	94.4 ab	88.3 b	83.5 b
Cajamarca 2 (T)	94.3 b	100.0 a	100.0 a
Fómeque1 (C)	92.7 b	81.1 b	74.0 b
Pasca (C)	50.8 c	85.0 b	91.3 b

[a] Prabhaker, N.; Coudriet, D.; Meyerdirk, D. 1985. Insecticide resistance in the sweetpotato whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae). J. Econ. Entomol. 78: 748-752; [b] Departments (C) = Cundinamarca, (T) = Tolima; [c] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ using the LSD test.

Ecuador zone: The mortality response of *T. vaporariorum* to methamidophos was low in 80% of the sampled sites in Ecuador. Although neonicotinoids (imidacloprid) are not widely used in the northern region of Ecuador, a slight decrease in the response to this insecticide was found in Chalguayacu (Table 97).

The excessive use of organophosphates in Ecuador is responsible for the significant increases in resistance levels through time (Figure 52). It is possible that the use of neonicotinoids at dosages below recommended levels has led to the development of resistance to neonicotinoids (Figure 53). No major changes were detected in nymphal populations.

Bemisia tabaci biotype B

The B biotype of *B. tabaci* has been shown to be more aggressive and to have a major capacity to develop resistance to insecticides. As can be seen in Table 98, the insect presents high levels of resistance to organophosphates, and intermediate levels of resistance to pyrethroids and neonicotinoids in Roldanillo (Cauca Valley of Colombia).

Table 97. Response (percentage mortality) of *Trialeurodes vaporariorum* adults to five insecticides in Ecuadorian provinces. Diagnostic dosages in µg vial $^{-1}$ were tested using insecticide-coated glass vials[a]. Diagnostic dosages in ppm, tested using the Cahill et al. (1996)[b] technique.

Race	methomyl (2.5 µg vial^{-1})	methamidophos (32 µg vial^{-1})	cypermethrin (500 µg vial^{-1})	imidacloprid (40 ppm)	thiocyclam hydrogen oxalate (1500 ppm)
CIAT	100.0 a[c]	93.8 a	89.7 b	88.2 bc	87.2 c
San Vicente	100.0 a	36.5 bc	96.9 a	83.7 cd	100.0 a
Chalguayacu	100.0 a	59.6 ab	100.0 a	72.0 d	100.0 a
Carpuela	100.0 a	24.7 c	100.0 a	92.9 ab	98.0 ab
Pusir	100.0 a	61.6 bc	83.8 b	97.0 a	95.7 b
Ibarra	100.0 a	31.3 bc	86.9 b	89.6 bc	100.0 a
Concepción	93.3 b	64.6 b	98.1 a	81.5 cd	100.0 a

[a] Plapp, F. W.; Jackman, J. A.; Campanhola, C.; Frisbie, R. E.; Graves, J. B.; Lutrell, R. G.; Kitten, W. F.; Wall, M. 1990. Monitoring and management of pyrethroid resistance in the tobacco budworm (Lepidoptera: Noctuidae) in Texas, Mississippi, Louisiana, Arkansas and Oklahoma. J. Econ. Entomol. 78: 748-752; [b] Cahill, M., K. Gorman, S. Day & I. Denholm. 1996. Baseline determination and detection of resistance to imidacloprid in *Bemisia tabaci* (Homoptera: Aleyrodidae). Bull. Entol. Res. 86: 343-349; [c] Means within a column followed by the same letter are not significantly different at the P = 0.05 using LSD test.

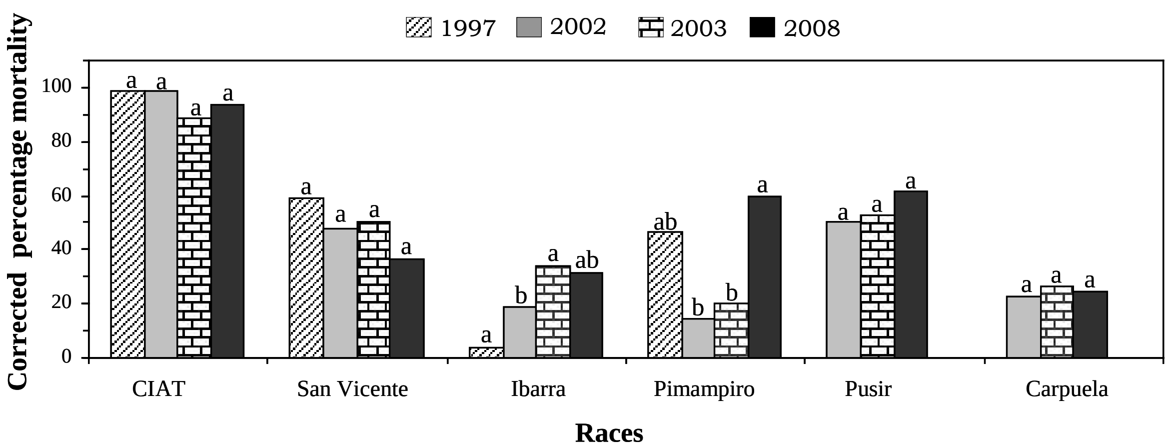

Figure 52. Changes in toxicological responses to methamidophos (32 µg vial^{-1}) in adult populations of *Trialeurodes vaporariorum* in Ecuador. Columns labeled by the same letter are not significantly different (P = 0.05) using the LSD test. Each site analyzed separately. CIAT = reference strains.

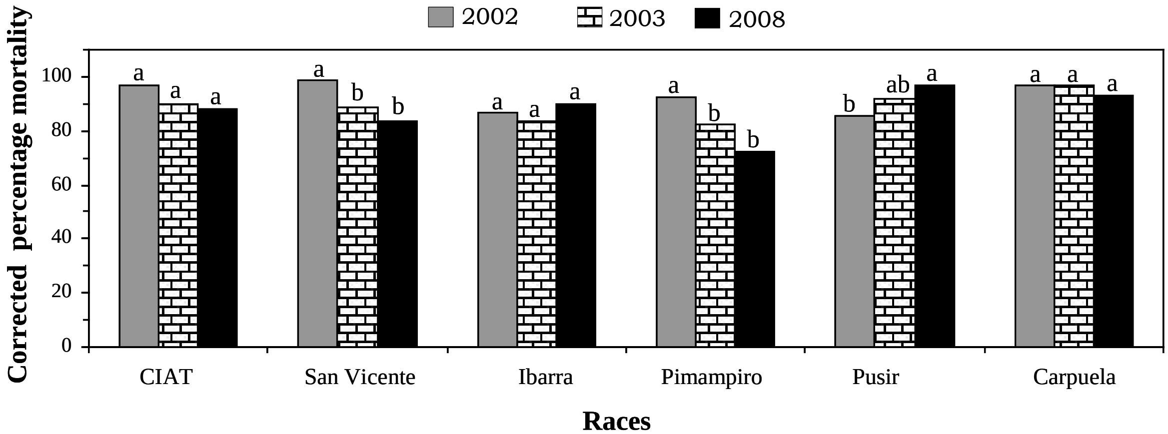

Figure 53. Changes in toxicological responses to imidacloprid (40 ppm) in adult populations of *Trialeurodes vaporariorum*. Columns followed by the same letter are not significantly different (P = 0.05) using the LSD test. Each site analyzed separately. CIAT = reference strains.

Table 98. Response (percentage mortality) of *Bemisia tabaci* B Biotype adults to five insecticides in Colombia and Ecuador. Diagnostic dosages in µg vial^{-1} were tested using insecticide-coated glass vials[a], Diagnostic dosages in ppm, tested using the Cahill et al. (1996)[b] technique.

Place (Country)[c]	methomyl (2.5 µg vial^{-1})	methamidophos (32 µg vial^{-1})	cypermethrin (500 µg vial^{-1})	imidacloprid (40 ppm)	thiocyclam hydrogen oxalate (1500 ppm)
Palmira (C)	100.0 a[d]	7.3 c	79.2 b	67.7 c	62.6 b
Cuambo(E)	99.0 a	47.9 b	96.9 a	94.8 a	100.0 a
CIAT	95.1 b	95.9 a	95.1 a	88.7 ab	94.0 a
Roldanillo (C)	89.9 b	25.0 bc	62.5 c	79.6 bc	94.7 a

[a] Plapp, F. W.; Jackman, J. A.; Campanhola, C.; Frisbie, R. E.; Graves, J. B.; Lutrell, R. G.; Kitten, W. F.; Wall, M. 1990. Monitoring and management of pyrethroid resistance in the tobacco budworm (Lepidoptera: Noctuidae) in Texas, Mississippi, Louisiana, Arkansas, and Oklahoma. J. Econ. Entomol. 78: 748-752; [b] Cahill, M., K. Gorman, S. Day & I. Denholm. 1996. Baseline determination and detection of resistance to imidacloprid in *Bemisia tabaci* (Homoptera: Aleyrodidae). Bull. Entol. Res. 86: 343-349; [c] Country (C) = Colombia, (E) = Ecuador; [d] Means within a column followed by the same letter are not significantly different at the P = 0.05 using LSD test.

The evaluation of nymphs was done with three insecticides. No significant changes were detected. The Roldanillo race in Colombia showed intermediate resistance to imidacloprid. In general, the response of *B. tabaci* nymphs (Table 99) is still that of susceptibility to the insecticides that were tested.

Table 99. Response (percentage mortality) of *Bemisia tabaci* B biotype nymphs to three insecticides in Colombia and Ecuador. Diagnostic dosages in ppm, tested using the Prabhaker et al. (1985)[a] technique.

Place (Country)[b]	buprofezin (16 ppm)	diafenthiuron (100 ppm)	imidacloprid (1000 ppm)
Cuambo(E)	100.0 a[c]	100.0 a	100.0 a
Palmira (C)	99.0 a	94.9 b	100.0 a
Roldanillo (C)	98.3 a	100.0 a	75.0 c
CIAT	93.4 a	100.0 a	91.6 b

[a] Prabhaker, N.; Coudriet, D.; Meyerdirk, D. 1985. Insecticide resistance in the sweetpotato whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae). J. Econ. Entomol. 78: 748-752; [b] Country (C)= Colombia, (E)= Ecuador; [c] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ using LSD test.

Thrips palmi Karny

T. palmi has become a major pest of vegetables and beans in Colombia and Ecuador. A survey showed that snap beans, dry beans, sweet pepper, melon, squash and cucumber are the crops most affected by this pest in the Antioquia Department of Colombia and in El Carchi province of Ecuador. Up to 60% of farmers surveyed in these countries use pesticides as the only method of control of thrips populations (see Annual Report 2007). Table 100 shows that in Colombia this insect has developed high levels of resistance to organophosphate and pyrethroid insecticides. In the Antioquia Department, novel products like pirazoles (fipronil) and, to a lesser extent, neonicotinoids, have lost effectiveness to control this insect.

Table 100. Response (percentage mortality) of *Thrips palmi* adults to six insecticides in Colombia. Diagnostic dosages in ppm, tested using the Cahill et al. (1996)[a] technique.

Place (Department)[b]	imidacloprid (1000 ppm)	spinosad (2000 ppm)	fipronil (100 ppm)	carbosulfan (1000 ppm)	cypermethrin (16 ppm)	methamidophos (16 ppm)
CIAT	100.0 a[c]	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Pradera (V)	100.0 a	100.0 a	60.0 c	100.0 a	3.0 d	1.0 e
Cajamarca1 (T)	100.0 a	100.0 a	100.0 a	100.0 a	13.3 c	8.9 de
Cajamarca2 (T)	100.0 a	100.0 a	100.0 a	100.0 a	15.2 c	5.1 de
C.Viboral1 (A)	83.5 b	95.1 c	78.6 b	86.4 c	12.6 bc	22.3 bc
C.Viboral2 (A)	83.2 b	95.0 c	25.7 d	26.7 d	5.5 cd	9.9 cd
C.Viboral3 (A)	83.0 b	92.0 c	64.0 c	82.0 c	10.0 c	24.0 b
El Cerrito (V)	56.0 c	97.0 b	85.0 b	95.0 b	29.0 b	7.0 de
Ubaque (C)	----	100.0 a	100.0 a	100.0 a	14.4 c	11.2 bcd

[a] Cahill, M., K. Gorman, S. Day & I. Denholm. 1996. Baseline determination and detection of resistance to imidacloprid in *Bemisia tabaci* (Homoptera: Aleyrodidae). Bull. Entol. Res. 86: 343-349; [b] Departments: (A)= Antioquia, (C)=Cundinamarca, (T)= Tolima,(V)= Valle de Cauca; [c] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ using LSD test.

In Ecuador, *T. palmi* showed a high incidence in the province of El Carchi. The levels of resistance evaluated with six products show the development of resistance to organophosphates, carbamate, and pyrethroid insecticides (Table 101). As in Colombia, resistance to products that had been recently introduced into the market were found to be high (imidacloprid and fipronil).

Table 101. Response (percentage mortality) of *Thrips palmi* adults to six insecticides in Ecuador. Diagnostic dosages in ppm, tested using the Cahill et al. (1996)[a] technique.

Place	imidacloprid (1000 ppm)	spinosad (2000 ppm)	fipronil (100 ppm)	carbosulfan (1000 ppm)	cypermethrin (16 ppm)	methamidophos (16 ppm)
CIAT	100.0 a[b]	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Chagualyacu	71.1 b	100.0 a	89.9 a	63.6 b	6.3 d	38.4 c
Carpuela	67.3 b	100.0 a	63.3 b	41.8 c	37.8 b	61.2 b
San Rafael	66.0 b	100.0 a	72.4 b	72.4 b	23.5 c	45.9 c
San Vicente	55.6 c	100.0 a	39.4 c	69.7 b	16.2 c	20.2 d

[a] Cahill, M., K. Gorman, S. Day & I. Denholm. 1996. Baseline determination and detection of resistance to imidacloprid in *Bemisia tabaci* (Homoptera: Aleyrodidae). Bull. Entol. Res. 86: 343-349; [b] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ using LSD test.

Leafminers (*Liriomyza huidobrensis*)

This insect is the cause of numerous applications in regions located above 1400 masl. Although it has very good biological control, the great amount of insecticides used in the zone affects populations of beneficial insects. This may be one of the reasons for periodic outbreaks of this pest in dry and snap bean crops. The continuous use of carbamates, pyrethroids and abamectines that in previous years were efficient to control this pest, has led to the development of intermediate resistance levels to these insecticides (Table 102).

Table 102. Response (percentage mortality) of *Liriomyza huidobrensis* adults and larvae to five insecticides in Colombia and Ecuador. Diagnostic dosages in µg vial^{-1} were tested using insecticide-coated glass vials[a], Diagnostic dosages in ppm, tested using the Ferguson (2004) technique[b].

Place (Country)[c]	Adults [a]			Larvae [b]	
	cypermethrin (2000 µg/vial)	chlorpyrifos (1000 µg/vial)	methomyl (3000 µg/vial)	abamectin (1000 ppm)	cyromazine (50 ppm)
Concepción (E)	99.0 a[d]	97.9 a	57.7 bc	100.0 a	85.9 a
CIAT	98.9 a	98.9 a	95.7 a	96.3 ab	97.9 a
C.Viboral (C)	97.8 a	96.8 a	90.3 a	---	---
San Vicente (C)	95.8 a	100.0 a	74.7 b	100.0 a	100.0 a
Pradera (C)	58.7 b	85.9 a	45.7 c	67.9 c	98.5 a
La Cumbre (C)	---	---	---	73.5 bc	100.0 a

[a] Mason, G. A., Johnson, M. W., Tabashnik, B. E. 1987. Susceptibility of *Liriomyza sativae* and *L. trifolii* (Diptera: Agromyzidae) to permethrin and fenvalerate. J. Econ. Entomol. 80 (6):1262-1266; [b]Ferguson, J. S. 2004. Development and stability of insecticide resistance in the leafminer *Liriomyza trifolii* (Diptera: Agromyzidae) to cyromazine, abamectin, and spinosad. J. Econ. Entomol. 97 (1):112-119; [c] Country (C) = Colombia, (E) = Ecuador ; [d] Means within a column followed by the same letter are not significantly different at the $P = 0.05$ using LSD test.

2.6.2 Continued monitoring of resistance to insecticides in *Bemisia tabaci*, on pepper hosts in Valle de Cauca

Rationale: *Bemisia* attacks multiple hosts, and the insect readily passes from one crop to the next. Mismanagement of the insect on one crop may lead to resistance to insecticides and thus increase problems on other crops. Knowledge of the behavior of *Bemisia* occurring on other crops is therefore relevant for beans and the potential for bean production. A study of the zones affected by *Bemisia tabaci* attacking hot and sweet pepper crops is one of our main responsibilities within the project “Development of a management system of *Bemisia tabaci* in hot pepper and sweet pepper in Valle de Cauca”, financed by the Ministry of Agriculture and Rural Development (MADR).

Materials and methods: Changes in the composition of white fly species and levels of resistance to insecticides in *B. tabaci* populations were monitored throughout the target area. The target area included the municipalities of La Unión, Roldanillo and Bolívar in the northern region of Valle de Cauca; La Cumbre, Yotoco, Trujillo and Restrepo in the central region; El Cerrito, Palmira and Pradera in the southern region (Figure 54). All these rural municipalities were selected because of their agricultural importance in terms of hot and sweet pepper production. Resistance levels to insecticides were measured on adult populations using the vial techniques adopted by the project. One carbamate (methomyl), one organophosphate (methamidophos), one pyrethroid (cypermethrine), one neonicotinoid (imidacloprid) and one nereistoxine (thiocyclam hydrogen oxalate) were chosen as most representative of the insecticides used by local farmers. To test nymphal populations, the growth regulators buprofezin and diafenthiuron and the neonicotinoid imidacloprid were used. CL_{50} and CL_{90} values were calculated for the novel insecticides pyriproxyfen and spiromesifen (Table 103). With this information, diagnostic dosages for these two products were calculated.

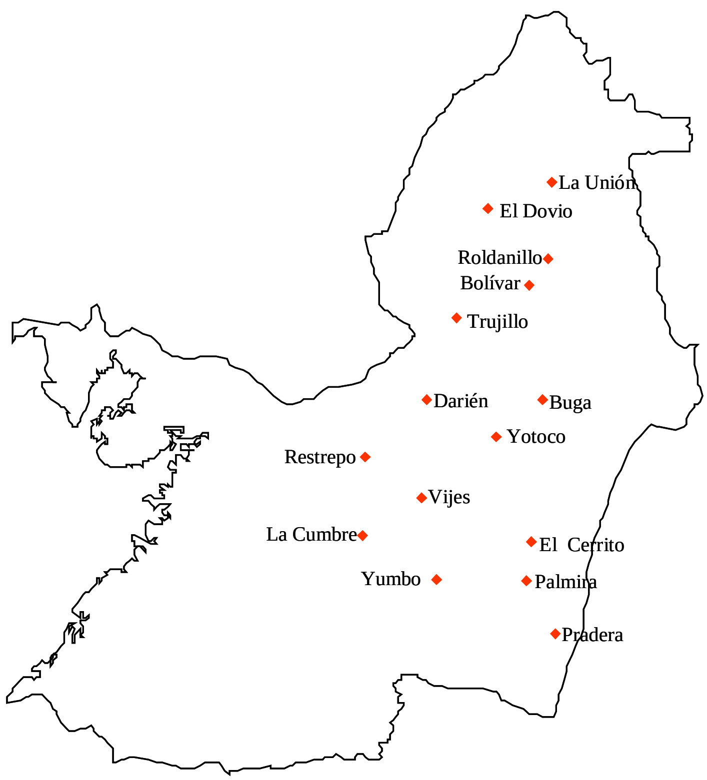

Figure 54. Target areas sampled and surveyed within the whitefly management project.

Table 103. Toxicological responses of laboratory races of *Trialeurodes vaporariorum* and *Bemisia tabaci* B biotype nymphs to two insecticides. Tests with spiromesifen and pyriproxyfen were conducted using the methodology suggested by Prabhaker et al. (1985)[a].

Species	Insecticide	n	Cl_{50} (LC 95%)	Cl_{90} (LC 95%)	b + SEM	χ^2
T. vaporariorum	spiromesifen	1064	0.2 (0.2 - 0.3)	5.4 (3.6 – 9.1)	0.9 ± 0.07	3.3
	pyriproxyfen	1593	0. 5 (0.4 - 0.6)	4.5 (3.5 – 6.1)	1.3 ± 0.07	3.4
B. tabaci B biotype	spiromesifen	1841	0.05 (0.04 - 0.07)	1.5 (1.1 - 2.3)	0.9 ± 0.05	1.7
	pyriproxyfen	2788	1.1 (0.9 – 1.3)	10.7 (8.9 – 13.1)	1.3 ±0.05	4.9

[a] Prabhaker, N.; Coudriet, D.; Meyerdirk, D. 1985. Insecticide resistance in the sweetpotato whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae). J. Econ. Entomol. 78: 748-752.

Figure 55 shows some of the results obtained in 2008. It is evident that adults of the *B. tabaci* biotype have developed high levels of resistance to methamidophos and cypermetrine, intermediate resistance to imidacloprid and thiocyclam hydrogen oxalate. Figure 56 shows that nymph populations of this biotype are still susceptible to buprofezin and diafenthiuron. Our results also show that in some areas of the Valle de Cauca (Roldanillo, Yotoco) the B biotype is in the process of developing intermediate resistance levels. This situation has to be reconfirmed because resistance to novel insecticides like the neonicotinoids would make management of the whitefly extremely difficult.

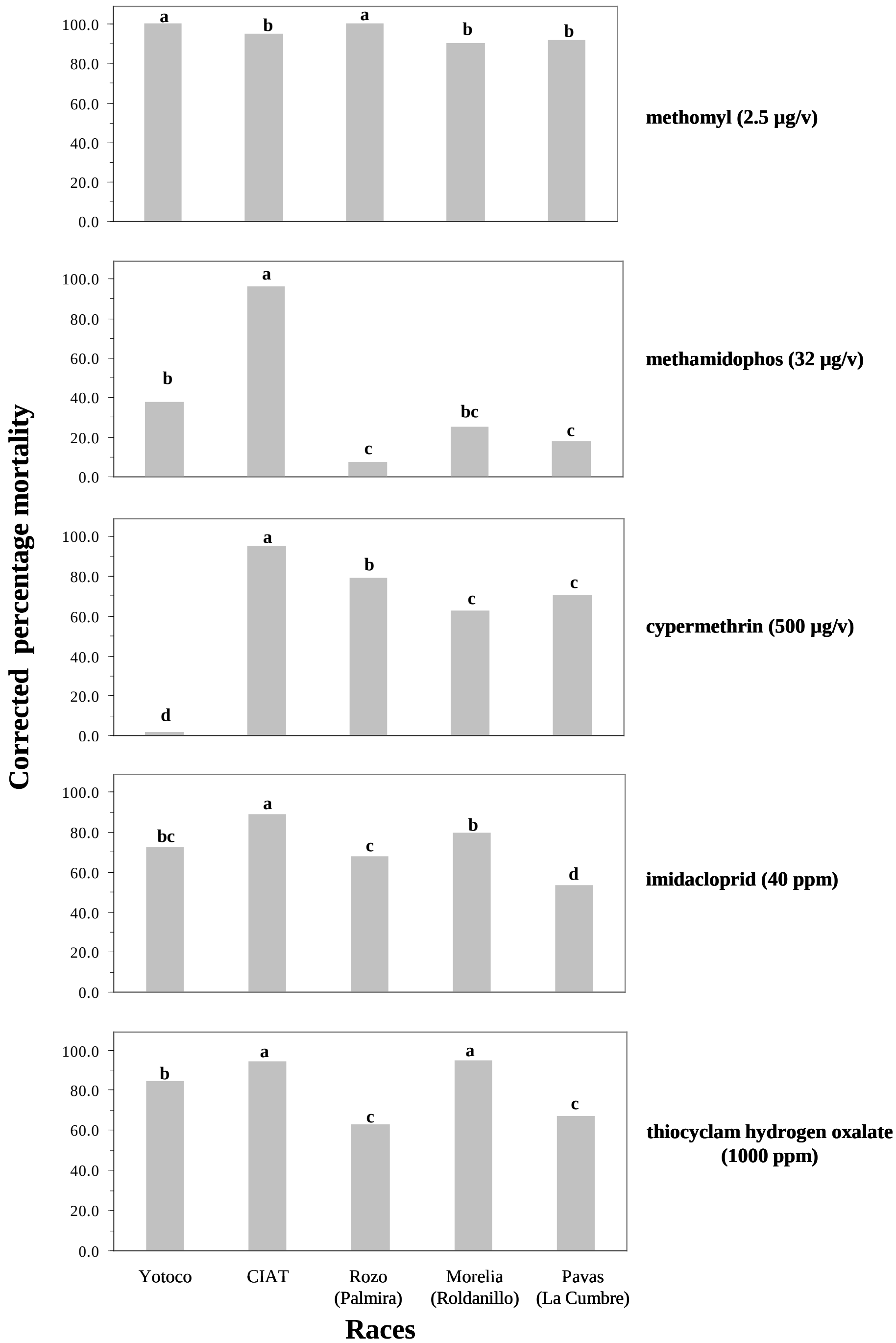

Figure 55. Toxicological response of adult populations of *Bemisia tabaci* B biotype to diagnostic dosages of five selected insecticides. Tests conducted in 2008. ¨CIAT¨ is the susceptible reference strain. Diagnostic dosages in µg $vial^{-1}$ were tested using insecticide-coated glass vials. Diagnostic dosages in ppm, were tested using the Cahill et al. (1996) technique.

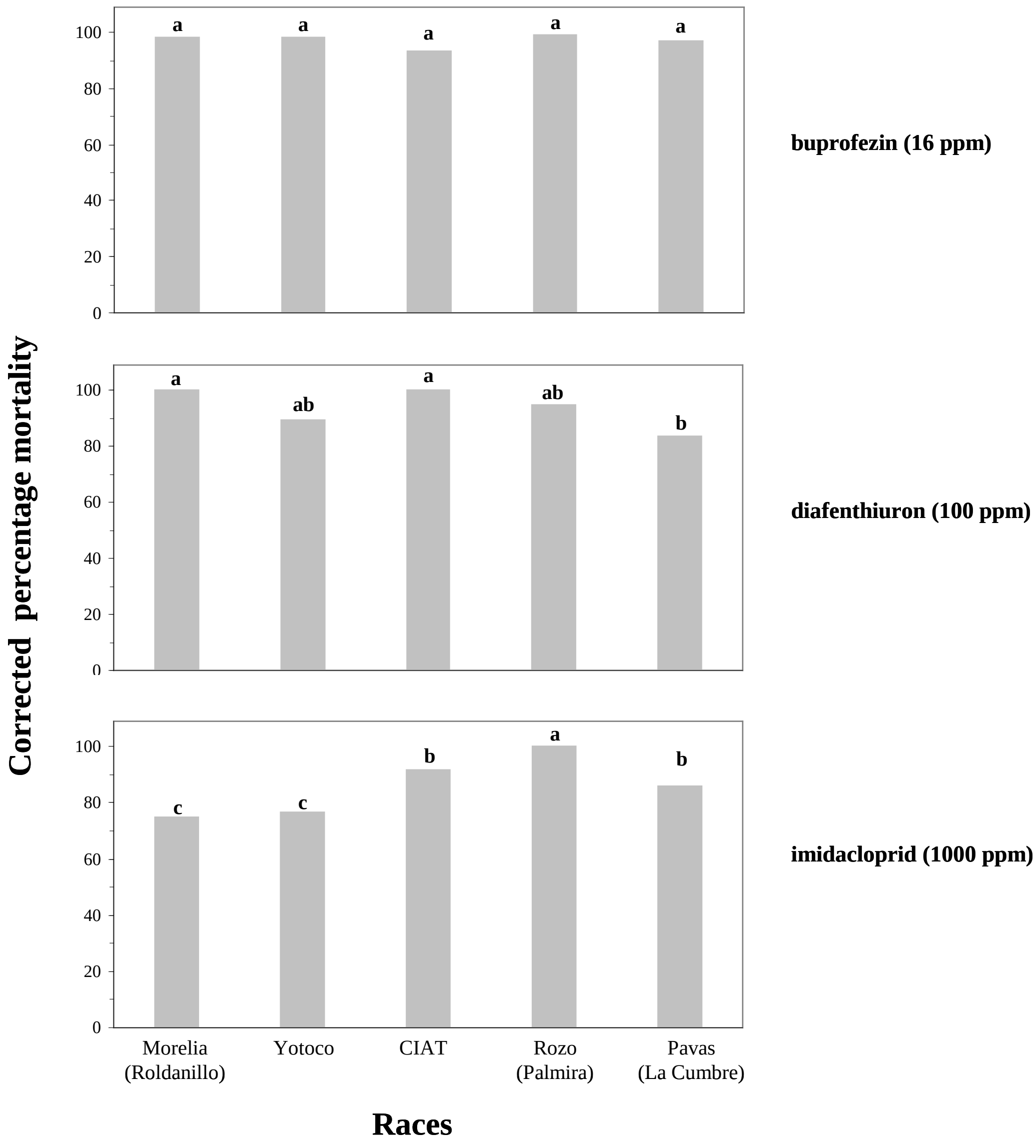

Figure 56. Toxicological response of *Bemisia tabaci* B biotype nymphs to diagnostic dosage of three selected insecticides in the Valle de Cauca in Colombia. ¨CIAT¨ is the susceptible reference strain. Diagnostic dosages in ppm tested using the Prabhaker et al. (1985) technique.

2.6.3 Isolation and assessment of 2,4-diacetylphloroglucinol (DAPG/Phl)-producing fluorescent *Pseudomonas* strains for biological control of *Pythium* root rots

Rationale: The genus *Pseudomonas* comprises the relatively large and important group of gram-negative, non-spore forming, motile rod bacteria. They produce a wide variety of antibiotics, which confer a competitive advantage and microbial fitness to survive in most environments (Haas and Keel, 2003; Paulsen et al., 2005). This genus also comprises beneficial bacteria such as plant growth promoters and biocontrol agents (Raaijmakers et al., 2002). Antibiotic 2,4-diacetylphloroglucinol (2,4-DAPG) is a polyketide compound with broad-spectrum antiviral, antifungal, antibacterial, and antitumor activity and phytotoxic properties (Raaijmaker et al., 2002; Haas and Keel, 2003). It is synthesized by several plant-associated fluorescent pseudomonads, and it plays a key role in the suppression of a wide variety of soil-borne diseases (Haas and Defago, 2005; Ramette et al., 2006). 2,4-DAPG inhibits zoospores produced by *Pythium* spp. and also damages the membrane of this Oomycete (de Souza, 2003b). The aim of this study was to isolate and assess the *in vitro* antagonistic potential of fluorescent *Pseudomonas* towards *Pythium* spp causing root rot in common beans.

Materials and Methods: Plant samples including maize (5), sorghum (2), pigeon peas (2) and beans (1) were collected from different sites (suppressive and non suppressive) around Kawanda Agricultural Research Institute. Isolation was done according to Mazzola et al., 2004. Briefly, the bean plants in their third growth phase (V3) were harvested, separated from the loose soil by gentle shaking and 0.5 g of the root system were excised from the plants and placed in 10 mL sterile distilled water. The roots and associated rhizosphere soil were vortexed for 60 s and serial dilutions of the resulting roots washed and plated on King's medium B (KB) agar amended with ampicillin (100µg mL^{-1}), chloramphenicol (13 µg mL^{-1}) and cycloheximide (75 µg mL^{-1}). Plates were incubated at 25°C for 48 h and colonies of fluorescent pseudomonads were differentiated from non-fluorescent colonies under UV light (wavelength 366 nm). Fluorescent pseudomonads were selected and transferred to fresh KB+ agar plates. A Gram stain was performed to examine to cell types.

Inhibition assays were performed using the central disk method (McSpadden Gardener et al., 2005). Agar plugs (6mm) containing the fungal mycelium, taken from the growing edge of each culture were placed in the centre of fresh potato dextrose agar (PDA) plates and incubated at room temperature for 24 h. A loop-full of fluorescent inoculum were inoculated at three equidistant positions along the perimeter of the assay plate. Two plates, one with no bacteria inoculum and the other with bacteria alone were included as controls. The assay plates were incubated at 24°C. Each bacterial isolate was replicated in three plates entire assay was repeated three times. Fungal growth was assayed when the growth on the *Pythium* control plates extended the full radius of the plate. Two measurements were made: distance from the edge of the plug to the growing edge of the fungus (X), and the distance from the edge of the bacterial growth to the growing edge of the fungus (Y). Inhibition index (I) was calculated as: I=Y/(X+Y) (McSpadden et al., 2005).

Results and discussion

After 48hrs of incubation, cream bacterial colonies could be observed growing at different intensities from different dilutions of all the 10 root washes. On examination under UV light, 9 isolates had mixtures of fluorescent and non fluorescent colonies. Of the 9 fluorescent isolates, one (from bean) was Gram positive and was excluded from further investigation. Eight Gram negative rod-shaped isolates found were tested for antagonism against *Pythium ultimum* isolate on Potato Dextrose Agar (PDA) plates according to McSpadden et al., 2005.

One isolate, P4 from pigeon peas, showed the highest antagonism with an inhibition index of 0.38 (Table 104, Figure 57).

Table 104. Inhibition indices of eight fluorescent *Pseudomonas* isolates from Kawanda

Isolate	X (mm)	Y (mm)	I
P1	26.5	8.5	0.24
P2	70	-26	-0.59
P3	40	-25	-1.67
P4	***15***	***9***	***0.38***
P7	44	0	0.00
P8	66	-23.5	-0.55
P9	47.5	-24.5	-1.07
P10	50.5	-22	-0.77

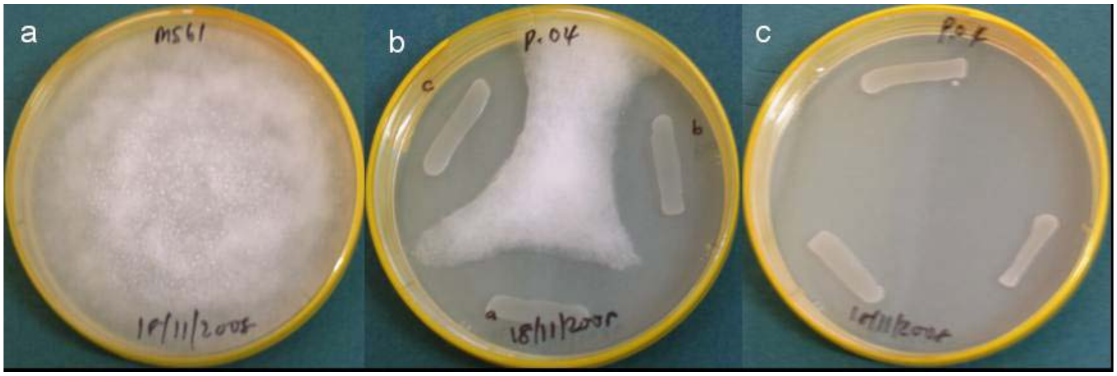

Figure 57. Petri dishes showing: a) *Pythium ultimum* alone, b) antagonism of *Pseudomonas* inoculated at 3 equidistant positions and c) *Pseudomonas* alone

Detection of 2,4-DAPG-producing fluorescent pseudomonads in Uganda has previously been conducted through extraction and PCR amplification of DNA from individual isolates (Kamenya, 2008). This detection is via amplification of phlD, which is a key gene in the biosynthesis of 2,4- DAPG. We have obtained these primers and will use it to detect the presence of the phlD gene in Pseudomonas isolate P4 and further screen more isolates for inclusion into this trial.

We will continue to explore the potential of antagonistic organisms to suppress *Pythium* spp. through further collections and screening. Our target will be suppressive soils that many authors propose are a reservoir of natural, effective and valuable microbial antagonists, and the chance of selecting effective biocontrol strains might be improved if isolations are made from such soils.

Contributors: Buruchara R., Buah S., Acam C.
Collaborators: Edema R. (Makerere University)

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2.6.4 Microsatellite analysis of common bean mixtures from SW Uganda

Rationale: Despite most consumers' preference for pure varieties in Uganda, small scale farmers in Southwester Uganda grow bean varietal mixtures. There are many reasons for growing varietal mixtures, but prominent among this is being risk averse and ensuring yield stability in the face of a variety of production constraints including *Pythium* root rots, one of the major diseases in the area.

We previously reported farmer's management strategies for bean root rots using the genetic diversity, morpho-agronomic and characterization and pathological reaction of components of bean mixtures against *Pythium ultimum*. The objective of this part of the study was to analyze the amount of genetic diversity associated with bean mixtures in Southwestern Uganda using Simple Sequence Repeats (SSR) markers. We expect that this information will be useful in developing strategies to manage, use and conserve the diversity in the region.

Materials and Methods:

Seed materials used: Representative seed samples (20%) of the different morpho-agronomically categories of the diversity of the bean mixtures (Franco et al., 2005) were used. Twenty seeds of each selected variety were planted in the field in a completely randomized block design with 2 replications. Plants in a population were tagged and sampled for DNA extraction. All tagged plants were harvested singly into paper bags and labeled accordingly.

Microsatellite DNA analysis: DNA was extracted from 2-week-old seedlings of the test materials. Twenty-three microsatellite primer pairs developed by various authors (Lioi et al., 2005; Yu et al., 2000; Gaitan-Solis et al., 2002; de Campos et al., 2007) were screened. As a result six pairs (Table 105) were chosen for full screening across all genotypes including CAL 96 and RWR 719 controls. The choice was based on clear polymorphism and stability of amplification.

Markers were amplified with a hot start of 94^{o}C for 5 min; followed by 10 cycles of a touchdown of decreasing annealing temperature by 1^{o}C/cycle until the optimal annealing temperature was reached; then 30 cycles of 94^{o}C for 30 sec, X^{o}C for 45 sec and 72^{o}C for 45 sec. (X was dependent on primer combination); followed by a final extension at 72^{o}C for 7 min and the reaction was held at 4^{o}C. The PCR reaction was carried out in a final volume of 20µl containing 10ng of genomic DNA, 0.1 µM of each of the forward and reverse primers, 10 mM of Tris-HCl (pH 7.2), 50 mM of KCl, 1.5 to 2.5 mM of $MgCl_2$, depending on the primer combination, 250 mM of total dNTP and 1 unit of Taq polymerase. The products were checked for amplification in 2% agarose gels and stained with ethidium bromide. Proper separation of both phaseolin and microsatellite alleles were achieved on 4% denaturing polyacrylamide gels. The gel was run in a vertical position at a constant voltage of 200V for 2.5 hours and bands were visualized by a silver staining procedure.

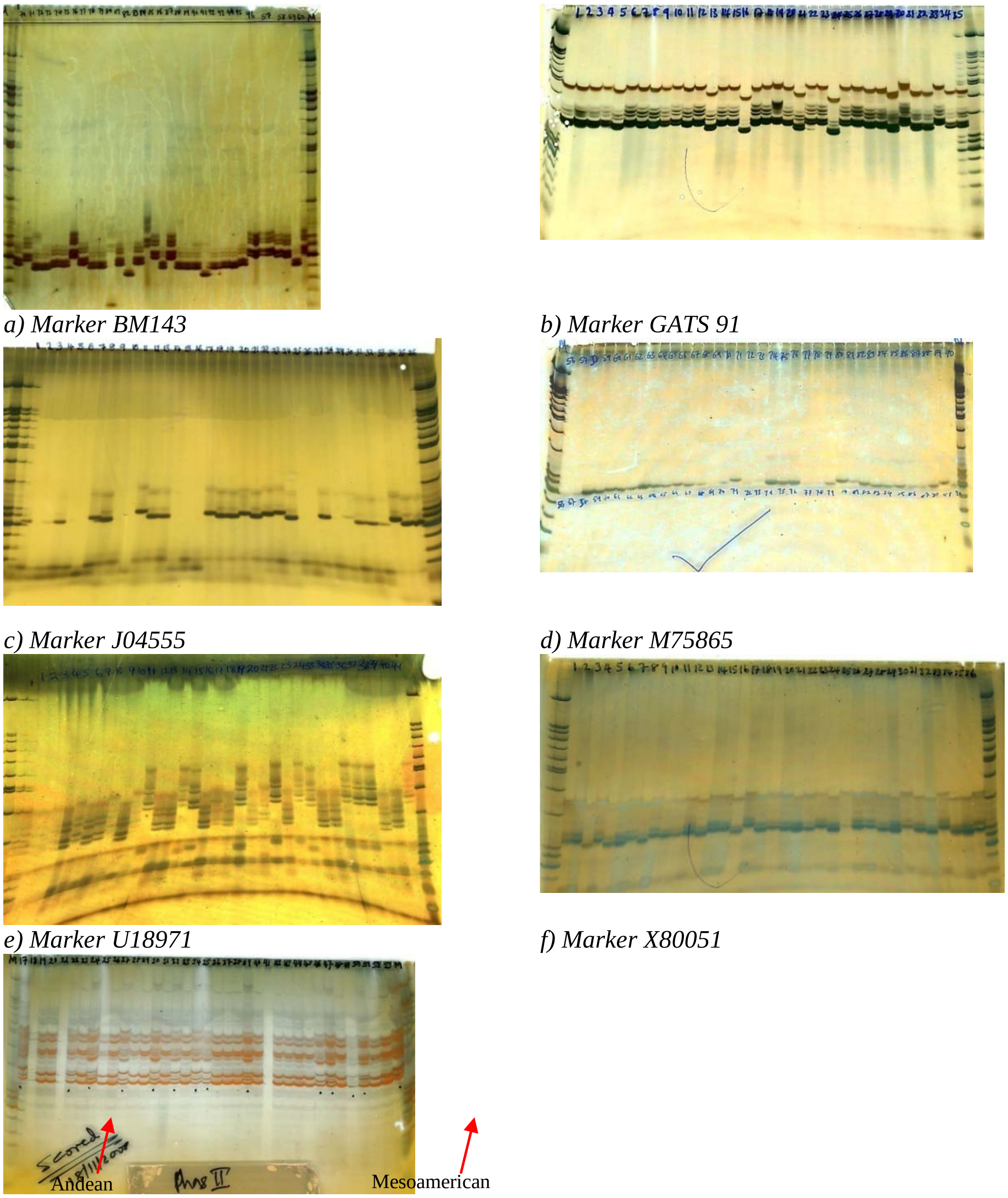
Table 105. SSR primers selected for bean diversity study.

Accession no.	Size (bp)	Forward primer	Reverse primer	Ta (°C)	Reference
J04555	152	GAGGGTGTTTCACTAT TGTCACTGC	TTCATGGATGGTGGA GGAACAG	51	Yu et al., 2000
M75856	157	CAATCCTCTCTCTC ATTTCCAATC	GACCTTGAAGTCGGT GTCGTTT	51	Yu et al., 2000
U18791	239	GGGAGGGTAGGGAAG CAGTG	GCGAACCACGTTCAT GAATGA	49	Yu et al., 2000
X80051	192	AGTTAAATTATACGA GGTTAGCCTAAATC	CATTCCCTTCACACAT TCACCG	49	Yu et al., 2000
GATS91	229	GAGTGCGGAAGCGAG TAGAG	TCCGTGTTCCTCTGTC TGTG	47	Gaitan-Solis et al., 2002
BM143	143	GGGAAATGAACAGAG GAAA	ATGTTGGGAACTTTTA GTGTG	42	Gaitan-Solis et al., 2002

Phaseolin analysis: Phaseolin, the major seed storage protein of common bean, was analyzed using primers developed by Kami et al., (1995) that differentiate S phaseolin gene family from the T phaseolin types. The S phaseolin genomic DNA, that is characteristic of the Mesoamerican gene pool, yields two homoduplex PCR products whereas T phaseolin DNA produce three homoduplex amplification bands that is characteristic of the Andean gene pool. Both phaseolin types produce identical smallest amplification products (Figure 58, g). The primer pair Phas1 (5'-AGCATATTCTAGAGGCCTCC-3') and Phas2 (5'-GCTCAGTTCCTCAATCTGTTC-3' was used under optimal conditions of 2mM$MgCl_2$, 200µM dNTPs, 0.2µM primers, and 40 cycles of 94°C for 30 s, 55°C for 30 s, and 72°C, for 45 s, with 10ng of DNA. Each clearly separated SSR amplification band was considered as an allele and coded for presence (1) or absence (0). The amount of genetic diversity was quantified using various indices implemented in the program ARLEQUIN version 3.11 (Schneider et al., 2007). The relationships between selected varieties and gene pool groups were derived from calculated genetic distances and dendrograms constructed with the neighbor joining method using NTSYS computer software.

Results and Discussion: A total of 39 alleles were obtained from the 5 loci amplified across all genotypes with an average of 7.8 alleles per locus ranging from 2 alleles for X80051 to 14 alleles for U18791 (Figures. 58, a-f). This observed average number of alleles is comparable to those obtained in other studies such as the average of 7.7 alleles reported by Maras et al., 2006. This finding suggests that a significant number of germplasm accessions have to be preserved in order to retain the original diversity. A total of 38 haplotypes were observed in the first 102 genotypes showing 36 polymorphic sites over the 39 alleles (94.7% polymorphism) and an average gene/allele diversity of 29.3% over the loci. Haplotype real differences were checked before tests (Ewens et al., 1972) and an observed and expected F values of 0.068 and 0.059 were obtained (p = 0.93).

The microsatellite analysis uncovered two major groups (Figure 59) corresponding to Andean and Mesoamerican gene pools based on the position of the control genotypes CAL 96 and RWR 719 in a cluster analysis performed using the Neighbor Joining method according to Nei (1978). There was a significant difference between the haplotypes of the two groups (F = 0.11, p = 0.000). However members of the Andean gene pool were much fewer than those of the Mesoamerican types. What was more remarkable was that, despite the few numbers, the Andean group was more diverse in terms of both haplotype diversity and percentage polymorphism compared to their Mesoamerican counterparts. This finding is in congruence with those of Santalla et al. (2004) who established that the Andean gene pool in Argentina has a large genetic base on the basis of morphological and adaptive variability as well as biochemical (allozymes and phaseolin) analysis. This high diversity in a susceptible group could be a result of the presence of infrequent alleles in the Andean group.



a) Marker BM143

b) Marker GATS 91

c) Marker J04555

d) Marker M75865

e) Marker U18971

f) Marker X80051

g) Phaseolin PCR

Figure 58. Microsatellite marker profiles on silver-stained polyacrylamide gels

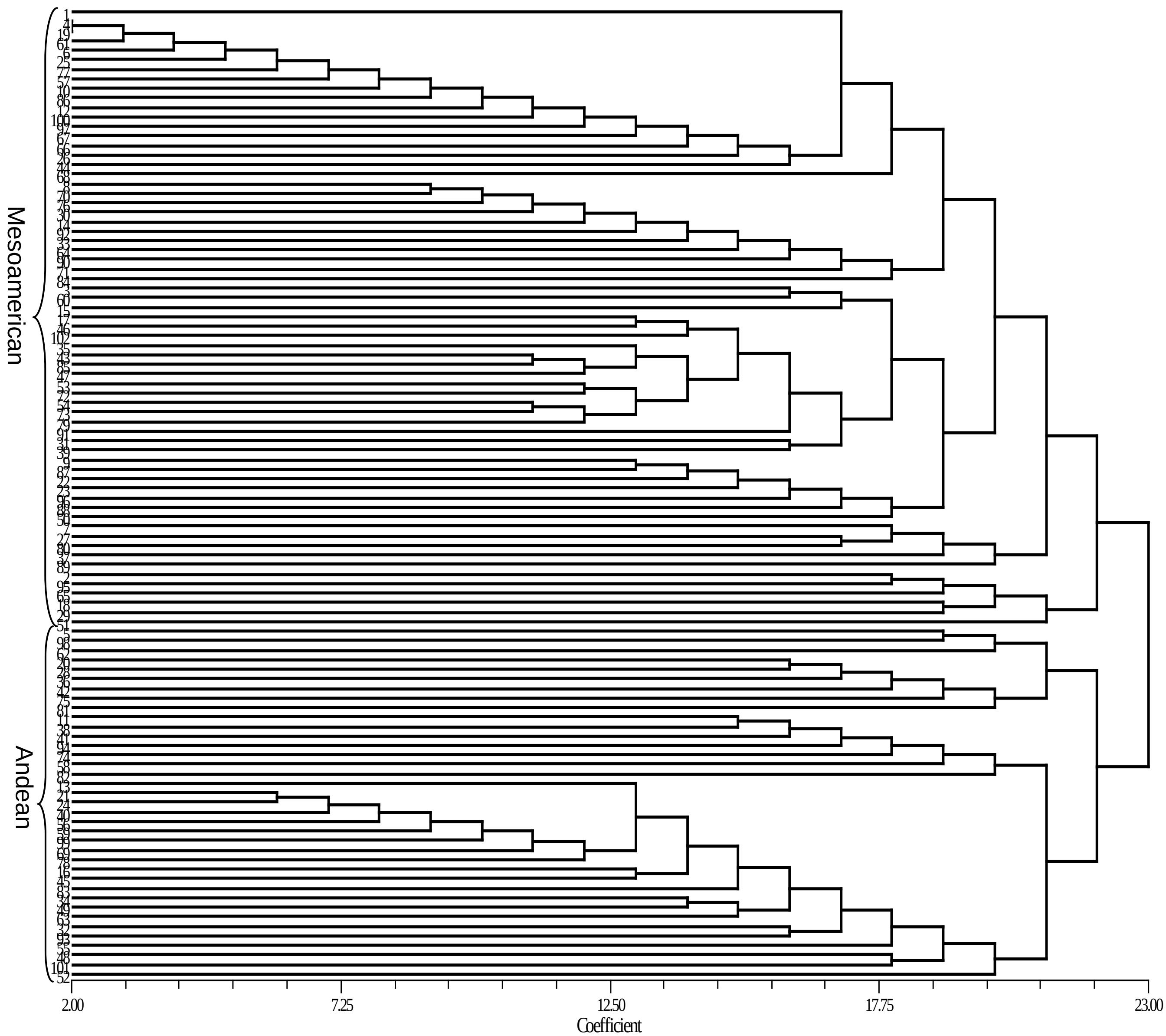


Figure 59. Microsatellite cluster analysis at 5 loci using NJ method.

Fewer genotypes were found in the Andean group than in the Mesoamerican group. The Andean clade was composed of 37 genotypes made of 16 haplotypes (43.2%). The observed and expected F values for this group were 0.12 and 0.10 respectively (p = 0.78). 71.8% of the loci were polymorphic for this group with a 9.62 mean number of pairwise differences.

The Mesoamerican group comprised of 65 genotypes and 22 haplotypes accounting for 33.8% haplotype frequency, almost 10 times less than the Andean haplotype frequency. Percentage polymorphism over loci was observed at 69.2% with a mean pairwise difference of 7.27. The observed and expected F values were the same as those of the Andean genotypes (p = 0.95). The dominant seed shape in the Andeans was elongate flat (69.4%) most of which presented primary coat colors of red (36.1%) and cream (25%). 58.3% of this group was monochromatic leaving only 15 genotypes which had secondary colors, 8 of which were cream, 5 purple and 2 brown. These secondary colors were mainly patterned as speckles or zebra stripes across the seeds. Mesoamerican genotypes, on the other hand, were principally comprised of round flat seeds (50%) bearing cream primary colors (54.7%). 67.2% of Mesoamerican seeds were monochromatic and the dominant secondary color occurring on 52.3% of the seeds in this group was black that were mainly mottled in pattern.

Urban markets mainly prefer large red mottled-to-maroon colored seeds most of which probably belong to the Andean gene pool. Hence farmers' sources of these seeds could have been markets or NGOs. Additionally, the patterns of secondary colors on seeds were mainly speckles or Zebra stripes for the Andean group and mottled in Mesoamericans.

Diversity in phaseolin types has been very useful for the classification of beans into Andean and Mesoamerican gene pools since most of the cultivars from one center of domestication possess a certain set of phaseolin type which is not found in cultivars from the other center of domestication (Duran et al., 2005). However, in this study the Andean group comprised of only 55.6% genotypes which possessed the T-type phaseolin characteristic of Andean races. Meanwhile 75% of the Mesoamerican genotypes had Type S phaseolin which is mainly used to designate this group.

Average yield per plant was slightly higher in the Mesoamerican group. In terms of pathogenicity, the overall average disease score for *Pythium* in the Andean group was 5.7 (standard deviation = 1.94) compared to 4.7 (standard deviation = 1.71) for the Mesoamerican group. This is consistent with previous findings that the genotypes of Mesoamerican origin are more resistant to the root rot disease (Buruchara, 2003). Since large-seeded Andeans have more market potential, we recommend crossing between the two gene pools to transfer original resistance genes from Mesoamerican genotypes into the Andeans with a major focus on those genotypes that have already been naturally introgressed.

Contributors: R. Buruchara, S. Buah, P. Okori (Makerere University)

Collaborators: Matthew Blair, Paul Gepts

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Product 3: Beans that respond to market opportunities

Activity 3.1 Development of large white beans for international markets

Highlights:

- Crosses have been developed to combine alubia grain type (uniform, milky white, long cylindrical seed) with drought resistance.

Rationale: International bean markets in some cases demand the same grain types as local and regional markets. For example, the small red type is widely accepted in Central America and in East Africa, and also finds a modest market in Pakistan and in the United States. Other types are cultivated in East Africa primarily for export, with a relatively minor component of local consumption, such as navy beans. Although productivity is relevant in such market types, meeting stringent market criteria to obtain the best prices often takes priority in farmers' choices of which varieties to plant. One of the highest value beans is the large white class, which in several parts of the world demands very high prices. In Spain for example, the very large fabada type sells for as much as US$10 per kilo. Alubia beans are one of the highest value types on the international market, and can sell for almost double the price of small black beans. The alubia type presents seed size and long cylindrical shape more typical of Andean beans, and with milky white grain. Argentina has been one of the largest producers of alubia beans, but East Africa has the opportunity to enter this market for sale to the mid-eastern countries. Some production of large white types already occurs in the region, but there is potential for much more.

Materials and Methods: In section 2.1.1.3 we reported on the development of large white beans for drought resistance. This is a particularly valuable trait for white beans, since production in dry areas is conducive to avoiding grain spotting and maintaining grain quality, but implies risk of drought. While the lines reported in the above section represent gains in agronomic traits, grain size and shape are still not adequate for the most demanding markets. It has been a particular challenge to obtain large, long cylindrical grain type with the best drought resistance, in spite of the fact that our drought resistant check, ICA Quimbaya (AFR 298) has excellent grain size and shape.

In 2008 F_2 populations developed within the drought breeding project were evaluated under intermittent drought. These included populations with alubia parents, and that were segregating excellent white color (milky, uniform, without veins or hilum discoloration). Out of F_2 families that expressed relatively good productivity under intermittent drought we selected the seed with the best grain color and to the extent possible, acceptable alubia size and shape, although grain type still fell short in this regard. These were crossed to ICA Quimbaya to recover the grain characteristics of Quimbaya with the alubia color. This represents a divergence from the standard drought breeding approach, in that it places primary importance on the grain characteristics. Additional crosses were planned to combine the sources of grain color with the best drought sources, as a back up plan to the crosses with Quimbaya. Crosses are presented in Table 106.

Results and Discussion: F_1 and F_2 seed was obtained for all combinations. Simultaneously, individual F_3 plant selections were taken within the lines that served as sources of alubia type to seek improved types in available families. All materials will be screened in the drought nursery in July, 2009

Collaborators: S. Beebe, M. Grajales

Table 106. Crosses to combine alubia grain color with improved grain size and shape and/or drought resistance.

Sources of commercial white color	Entry	Sources of grain form and/or drought resistance				
		Quimbaya	SAB 618	SAB 630	SAB 650	SAB 686
(G 7930 x SAB 621)F_1 x SAB 686/-MC	155	X	X	X	X	X
(G 7930 x SAB 621)F_1 x ICA QUIMBAYA/-MC	159					X
(G 7930 x SAB 621)F_1 x ICA QUIMBAYA/-MC	160	X				X
(G 7930 x SAB 621)F_1 x ICA QUIMBAYA/-MC	162					X
SAB 676 x(G 7930 x SAB 634)F_1/-MC	164	X				X
(G 7930 x SAB 634)F_1 x ICA QUIMBAYA/-MC	170	X				X
ICA QUIMBAYA x (SAB 620 x SAB 634)F_1/-MC	226	X				X

Activity 3.2 Breeding Navy and Large White bean varieties with multiple stress resistance in eastern Africa

Highlights:

- Fourteen new navy and large white bean varieties combining multiple resistance to diseases and abiotic stress factors, high yield potential and marketable grain characteristics released for smallholder production in four countries in eastern Africa

Introduction: Smallholder farmers in East and Central Africa predominantly grow small white bean (also known as white pea or navy bean) for export and local canning industries. Navy beans are grown on an estimated 310,000 ha per year and account for 9.6% of total bean production in Africa. They are particularly important in Ethiopia and Sudan. Ethiopia is the leading producer of navy bean in East and Central Africa. Farmers in the Rift Valley region of Ethiopia export nearly 90% of their navy bean. Navy bean is also important in Nile Valley of Sudan, southwestern Uganda, northeastern Tanzania, Kenya, Madagascar, Cameroon and the Great lakes region where it is a component of the mixtures (Wortmann et al., 1998). They are in high demand for the canning industries of Kenya, South Africa and Zimbabwe and in urban areas where they are popular because of their taste, short cooking time and low levels of flatulence. However, yields of navy bean under low input systems common in eastern Africa are low, typically 400 to 700 kg ha^{-1} due to susceptibility to diseases such as rust, common bacterial blight, anthracnose, angular leaf spot, root rots and edaphic stresses such low soil nitrogen and phosphorus, and drought.

Large white bean is an important commodity for domestic and export markets of Madagascar and Sudan. Large white is gaining popularity in Ethiopia. Large whites are mostly exported from Madagascar (CTHA and Masumin exporters), Sudan, Ethiopia, Rwanda and D. R. Congo. Uganda is evaluating two varieties for Saudi Arabian markets. They tend to be susceptible to rust, common bacterial blight and angular leaf spot. Most of the commercial varieties are susceptible to diseases. There is need to identify desired varieties for new and emerging markets. There is indication that the Spanish types are more popular in the export markets. Development of improved cultivars of navy and large white beans has been one of the priorities of the market-led breeding program of the East and Central Africa Bean Research Network (ECABREN). A regional breeding program was started in 2001 to develop improved, marketable navy and large white bean cultivars with resistance and/or tolerance to two or more priority constraints. Selection for improved lines was conducted collaboratively at Melkassa (Ethiopia), FOFIFA in Madagascar, and University of Nairobi in Kenya from existing and new breeding populations. The navy bean program is led by Ethiopian National Bean program (EIAR), large white program by FOFIFA bean program in Madagascar with back up programs at the University of Nairobi, Kenya and CIAT, Colombia. This report highlights some of the main achievements of this collaborative research for development program.

Materials and Methods: A working collection was made from segregating populations, advanced lines, commercial cultivars, breeding populations, and constraint nurseries held by CIAT programs in Uganda, Colombia, Kenya and the Ethiopian national program. Parental lines from this collection were used for crossing programs at Kabete (Kenya), Melkassa Agricultural Research Centre, Nazareth (Ethiopia) and FOFIFA (Madagascar).

One hundred thirty three pollinations were made at Kabete to transfer anthracnose and rust resistance from Roba-1 to Mexican 142. Mexican 142 is probably the oldest canning variety in the region and one of the few varieties which adequately meets the stringent canning requirements. It is however very susceptible to rust and anthracnose. It has type III growth habit. Farmers prefer type I growth habit because of ease of harvesting and threshing. We also made 97 pollinations to combine the high canning quality, tolerance to rust, bean stem maggot resistance and type 1 growth habit of Awash 1 with high yield potential and resistance to anthracnose of Goberasha. The F_1 was backcrossed to Mexican 142 to generate segregating populations. Navy bean grain type was selected from 52 F_2 segregating populations at Kabete Field Station, and used to establish F_3 progeny rows. Progeny rows were rated for disease reaction, plant type and tolerance to moisture stress at Kabete. F_4 bulks were evaluated for tolerance to low soil P at Kakamega and root rots in Sabatia test sites. The F_4 bulks, F_5 and F_6 lines were grown in preliminary and intermediate yield trials at three locations. Thirty-eight new lines were finally selected for regional distribution and advanced yield trials.

In Melkassa, crosses were made to generate new breeding populations. The adapted parents in the new crosses were PAN 182, Dresden, Mex 142 and Awash 1. Donor parents for anthracnose were Roba and Goberasha. PAN 182 and Awash contributed resistance to rust. HAL–5 was used a source of resistance to halo blight. A262, A197 and TY 3396-3 were included in these crosses due to their high yield potential. Awash also contributed type 1 growth habit. Dresden has excellent canning quality but is susceptible to anthracnose, CBB, rust and angular leaf spot. The first single crosses were made in 2000 main season. Development of three way, double and backcrosses started during the 2001off-season. Included in these crosses was 'Omar', a medium sized white bean that was identified by exporters for its quality. It is however susceptible to rust and other diseases. In Ethiopia, advanced lines were evaluated in multi-location trials.

In Madagascar, selection was conducted from 19 advanced lines from the regional program at Kabete, and from new populations generated from crosses between Ranjonoby (a commercial large white variety) and sources of resistance to angular leaf spot, anthracnose , rust, common bacterial blight and tolerance to low soil fertility (Ikinimba). Ikinimba has shown good levels of resistance to rust, angular leaf spot, anthracnose and low soil fertility under Madagascar conditions. Awash was used as source of resistance to rust and anthracnose. XAN 74 was source of resistance to common bacterial blight. F_1 were backcrossed to Ranjonoby for three generations.

Results and Discussion: Ten high yielding small white lines were selected from the preliminary and intermediate trials in Kenya. Some of their characteristics are shown in Table 107. Mean yields across sites were above 2 t ha^{-1}. DB 190-84-1, ECAB 0601, ECAB 0628, UBR(92)17-1 and UBR(92)25-27 succumbed to rust at Thika and were discarded. All other lines showed resistant or intermediate reactions (1 to 9 on CIAT rust scale). ARA 8-4-1 and BL 207562 were susceptible to black root. All lines showed resistance to angular leaf spot and anthracnose. Selected F_8 lines were evaluated at Kabete and Thika over three seasons.

Table 107. Days to flowering, maturity, seed mass and grain yield of best 10 navy F_6 bean lines selected from segregating populations and other nurseries in eastern Africa.

Genotype	Days to 50 % flower	Days to 75% maturity	100-Seed mass (g)	Yield (kg ha^{-1})		
				PYT[a] (3 sites)	IYT[b] (2 sites)	Mean
BRB 148-1	45.5	89	23.7	3129	3002	3066
ECAB 00621	54.5	100	28.4	2690	2299	2495
BL 207562-1	46.9	90	27.0	2861	2084	2473
ECAB 00622	50.7	96	24.6	2210	2559	2385
ECAB 00612	50.5	94.7	18.4	2367	2348	2358
ECAB 00605	53.3	95	23.5	2936	1771	2354
ECAB 00624	52.7	97	24.8	2652	1972	2312
BRB 45-1	47.8	91	24.0	2713	1838	2276
ECAB 00623	55.0	99	21.7	2528	2015	2272
ECAB 00625	49.8	95	26.8	2777	1760	2269
Trial mean	49.9	94.7	24.5	2319	1911	2115
Genotypes (G)	**	**	**	**	*	
Locations (L)	**	NS	**	**	NS	
G XL	**	**	**	**	*	
LSD $_{0.05}$	2.6	2.9	1.9	423.2	621	
CV(%)	4.5	2.7	7.0	18.2	32.5	

*,** : Significant at 5 and 1% probability levels, respectively; NS= not significant. PYT[a] = preliminary yield trial of F_5 ; IYT[b]= intermediate yield trial of F_6 and other advanced lines.

Thirty-eight advanced lines were evaluated in multi-location trials in Kenya and compared with regional check varieties. Results showed significant genotypic differences for days to flower, maturity, rust, pod load, 100-seed mass and grain yield (Table 108). Effects of environment were significant for all traits (P>0.01). A significant genotype x environment interaction was detected for phenology, rust, pods m^{-2}, 100-seed mass and grain yield. Rust was most severe at Kabete. Sarrag was rated very susceptible in three of the four environments with scores of 9, 9 and 8.3, respectively (CIAT scale). HRS was rated susceptible at Kabete with a score of 7. Mexican 142 showed intermediate score of 3.7 at Kabete and 4.3 at Thika. Awash 1 showed intermediate score of 3.6 for the two seasons at Kabete. ECAB 0614, ECAB 0617 and ECAB 0619 had intermediate rust scores at Kabete. ECAB 0602 also had an intermediate rust score of 3.7 at Juja. All other test lines showed resistant reactions to rust. Root rot was most severe at Kabete. ECAB 0602, ECAB0631 and ECAB0632 had scores of 5, 4.3 and 3.7, respectively at this site. All other lines and checks showed resistant reactions. Mean grain yield was lowest at Kabete during the long rain season and highest at the same site during the short rain season (Table 108). This was partly attributed to effects of rust and moisture stress at Kabete. Results showed that 37 new lines produced more grain than the best check (Mexican 142) (Table 108). ECAB0601 was the best line among the new lines with a high yield advantage over the check varieties. The results indicated that new lines have considerable yield potential compared to the commercial cultivars. However, these lines need to be evaluated for canning quality.

In Ethiopia, advanced lines were evaluated in multi-location trials at Alemaya, Awassa, Bako, Jimma, Melkassa, Ziway, Ambo, Mekele, Asassa, Adet, Pawe and Sirinka. Four lines promising were identified. These were UTT 24-131, UTT 27-24, NZBR 2-5, BZBR 2-8 (Teshale et al., 2007). Several lines were selected at Melkassa and Alemaya for the national yield trials (NYT) and farmer verification trials (FVT) under the supervision of the National Variety Releasing Committee (NVRC). Similar evaluations were conducted in Madagascar and Sudan.

Release of New Varieties: Table 109 shows some of the new navy and large white varieties released or pre-released in eastern Africa between 2003 and 2008. RJ 1, RI 5-1, RI 5-5, RI 5-3, IL 5-53 are large seeded. They were selected from populations developed in Madagascar. Ibarya and Mutwakil have medium sized seeds (29 to 37 g/100 seed) but considered as large seeded in Sudan. Most of the new releases have resistance to two or more biotic and abiotic stresses. CAB 19 is a small white climbing bean released in Tanzania but originated from Rwanda.

Contributors: Paul Kimani, Teshale Assefa (Ethiopia), Amee Rakoriahanta (Madagascar), Bulti Tesso and Chemeda Fininsa (Alemaya University, Ethiopia), Festo Ngulu (Tanzania) and Ghamal Khalifa (Sudan)

Collaborators: Hery Andrimazaolo (Madagascar) and Bean Teams at Kabete (Kenya), Melkassa (Ethiopia), FOFIFA (Madagascar), Alemaya (Ethiopia) and Hudeiba (Sudan)

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Table 108. Mean duration to flowering, maturity, pods m^{-2}, 100-seed mass and grain yield of selected F_8 navy bean lines grown at four environments in Kenya

Genotype	Days to 50% flower (d)	Days to maturity (d)	Pod m^{-2}	100-seed mass (g)	Grain yield ($kg\ ha^{-1}$)				
					Kabete SR	Kabete LR	Thika SR	Juja LR	Mean
ECAB0601	47.0	89.5	239.7	24.5	2329	2490	2805	2686	2578
ECAB0627	46.2	87.3	234.3	23.5	2688	2501	2001	2299	2372
ECAB0612	46.9	87.4	268.9	20.5	2389	1702	2723	2538	2338
ECAB0629	46.4	88.7	247.6	24.4	2204	2470	2262	2325	2315
ECAB0608	45.9	86.9	225.8	22.2	2283	1684	2578	2571	2279
ECAB0614	45.8	87.8	234.6	22.3	2568	1307	2542	2554	2243
ECAB0603	46.2	87.8	236.1	20.2	2824	1420	2205	2181	2158
ECAB0617	47.8	88.9	232.1	19.5	2658	1621	1730	2503	2128
ECAB0604	46.9	88.3	233.6	20.0	1860	1743	2471	2421	2124
ECAB0621	48.5	88.5	218.9	20.5	2809	1669	2472	1416	2092
ECAB0615	47.4	89.2	239.3	22.6	1975	2075	1983	2170	2051
ECAB0607	46.9	87.9	226.5	22.7	2086	1252	2539	2279	2039
ECAB0611	45.6	88.1	222.2	22.3	2622	1707	2771	977	2019
ECAB0620	47.1	88.5	237.2	22.0	2670	1314	1905	2180	2017
ECAB0616	44.7	85.7	225.8	22.8	2050	1660	1879	2406	1999
ECAB0610	47.2	88.2	225.4	21.2	2611	925	1829	2415	1945
ECAB0630	44.7	85.8	225.0	18.2	2562	1692	2338	918	1878
ECAB0613	47.3	87.4	233.4	21.4	2243	983	1823	2357	1852
ECAB0619	47.6	88.3	236.5	21.7	2365	816	1676	2548	1851
ECAB0623	47.9	89.7	218.2	21.1	2445	1169	2456	1209	1820
ECAB0606	47.5	88.0	208.0	20.0	2326	861	1716	2220	1781
ECAB0632	45.9	86.7	223.9	20.9	1852	1268	2259	1644	1756
ECAB0622	47.8	88.8	218.2	21.5	2411	1772	260	2508	1738
ECAB0609	46.7	86.6	229.1	22.7	2255	281	1830	2541	1727
ECAB0628	44.2	85.4	204.8	25.3	2389	1539	1427	1536	1723
ECAB0626	46.1	87.1	198.3	23.2	2356	1613	988	1892	1712
ECAB0624	37.8	88.3	228.0	21.6	1985	2275	1686	895	1710
ECAB0634	44.8	85.7	214.6	25.9	2396	1304	1056	1889	1661
ECAB0637	45.0	86.8	220.7	25.9	2271	830	1721	1751	1643
ECAB0633	44.2	86.3	239.7	23.5	2380	1908	630	1635	1638
ECAB0635	34.6	86.0	241.5	26.2	1888	1546	852	2245	1633
ECAB0618	46.2	87.7	220.6	20.7	2515	1203	1318	1432	1617
ECAB0605	38.0	88.3	238.9	21.6	1976	1549	2300	622	1612
ECAB0636	44.4	85.6	235.2	23.3	1154	1112	1549	2319	1534
HRS 545	43.3	83.4	218.7	21.6	2032	1450	1261	1295	1510
ECAB0602	45.2	86.4	203.7	26.2	939	861	2683	1432	1479
MEXICAN 142	43.3	85.3	214.1	18.4	1981	1127	825	1792	1431
BASSABEER	43.2	84.6	231.1	22.6	1415	1123	1908	1086	1383
ECAB0625	46.6	87.9	228.5	24.1	2609	1817	940	151	1379
ECAB0631	46.0	87.0	232.6	23.1	717	1200	1274	1916	1277
AWASH 1	41.5	83.9	208.3	19.5	1311	557	1561	1077	1127
SARRAG	44.1	86.3	200.4	23.8	2340	591	1086	447	1116
Environmental mean	46.0	87.2	227.0	22.4	2184	1452	1868	1873	1844
C.V.(%)	3.9	2.3	20.9	7.4					18.2
Replications	NS	NS	NS	NS					NS
Genotypes (G)	**	**	NS	**					**
Environments (E)	**	**	**	**					**
G x E	**	**	*	**					**

*, **: Significant at 5 and 1 % probability levels, respectively; NS= not significant

Table 109. Navy and large white varieties released in eastern Africa between 2003 and 2008.

Variety	Line Code	Year of Release	Country of release
Cheupe	CAB 19	2008	Tanzania
RJ1	RJ1	2008	Madagascar
RI 5-1	RI 5-1	2008	Madagascar
RI 5-5	RI 5-5	2008	Madagascar
RI 5-3	RI 5-3	2008	Madagascar
IL 5-53	IL 5-53	2008	Madagascar
Cranscope	Kranskop	2007	Ethiopia
Argane	AR04GY	2005	Ethiopia
TAO4 JI	TAO4- JI	2005	Ethiopia
Chercher	STTT-165-96	2006	Ethiopia
Chore	STTT-165-92	2006	Ethiopia
Hirna	STTT-165-95	2006	Ethiopia
Mutwakil	Berber Large	2003	Sudan
Ibarya	ABA 61	2003	Sudan

Source: National Bean program reports 2004-2008.

Activity 3.3 Identification of a varietal candidate in Nicaragua with potential for international export

Highlights:

- The bean program of INTA-Nicaragua has selected a line for varietal release with the purpose of exporting grain to the USA.

Rationale: Beans have become increasingly commercial and are an important income earner in both Latin America and Africa. Surveys in rural Nicaragua indicated that beans rank among the top three income generators for more that 90% of the population. With many million of Latins now living in the USA, a population with increased buying power is willing to pay for traditional foods imported from the home country. Thus Nicaragua has organized a value chain to link farmers producing traditional red beans with the “nostalgia” market in the United States. Landraces with light red color have serious phytosanitary problems that have been solved in improved varieties with darker color, but now there is a demand for lines with color comparable to the landraces that also have improved agronomic traits.

Materiales and Methods: In August, 2005 lines were selected by the Nicaraguan breeder in CIAT’s drought breeding nurseries in Cali, Colombia based on drought performance and commercial grain color. Among these was the line SM15212-33-3, derived from the parents SER 38 x (MAB 87 x SER 31). MAB 87 was developed for resistance to angular leaf spot (ALS) and is derived from G10474, a climbing bean from Guatemala that presents the widest known resistance to races of *Phaeoisariopsis griseola*, causal agent of ALS. The line was dubbed “628” in Nicaragua in reference to its serial number in the original nursery. Line 628 stood out for its excellent grain type. It was shipped to Nicaragua and underwent reselection and systematic evaluation for agronomic traits and culinary characteristics.

Results and Discussion: Line 628 has now advanced through regional and validation trials. In the process it has proven to have stable resistance to races of ALS in Nicaragua. ALS has been increasing in importance over the past decade and has reached dangerous levels in most countries. If Line 628 is released, it will be the first variety in Central America to be bred specifically for ALS resistance. This is relevant for the commercial market, since ALS causes early defoliation and reduced grain size and quality.

Anecdotally, Line 628 also has proven to be relatively tolerant to excess rainfall. One farmer reported that while the local variety was totally lost in the unusually rainy "postrera" season (September-December) of 2008, Line 628 produced nearly 300 kg ha^{-1}.

In the very dry north of Nicaragua in Somoto, Line 628 was one of the better yielding lines in the "primera" season (May-August), although in most environments it is not outstanding in yield. Its advantage, in addition to its resistance to ALS, is its commercial quality and color. In the 2008 "postrera" season, a farmer association planted 44 hectares for seed production, even though the line is not officially released. Unfortunately, given the unfavorable climatic conditions, little was harvested. It is expected that formal release with take place in 2009.

Collaborators: S. Beebe, M. Grajales, C. Cajiao, A. Llanos, J. Molina, R. Urbina

Activity 3.4 Progress in development of Snap and runner beans for smallholder production in East and Central Africa

Highlights:

- Twenty bush and climbing snap bean lines with consumer preferred pod characteristics and resistance to diseases selected in four countries in eastern Africa.
- Nineteen new short-day runner bean lines with high pod yield potential selected making smallholder production under short-day conditions in eastern Africa feasible.

Rationale: Snap bean (*Phaseolus vulgaris* L.) and runner beans (*Phaseolus coccineus* L.) are the probably the most important high value beans grown in East and Central Africa. They are mainly grown for export markets but the domestic markets especially in urban areas are growing rapidly. It is a major source of income for smallholder farmers especially in Kenya, Uganda, Sudan, Tanzania, Madagascar in eastern Africa and Senegal, Cameroon and other countries in West Africa. Snap beans, also known as French beans are grown in North Africa for export to Europe and Middle East. There is growing interest to increase snap bean production for domestic and export markets in Rwanda, Ethiopia, Burundi, and other countries in East and Central Africa. Snap bean is also grown by large commercial companies for export to overseas supermarkets and for canning industries. Yield of snap bean in smallholder farmers' fields varies from 2 to 8 t ha^{-1} (CIAT, 2004), compared to over 14 t ha^{-1} among large scale producers. Smallholder production is constrained by diseases especially rust, angular leaf spot, root rots, bean common mosaic virus and pests especially bean stem maggots, thrips and nematodes. The intensive nature of cultivation of this crop leads to high disease and insect pressure, and consequently excessive use of pesticides. Smallholder production is further constrained by high costs of seed because most of the varieties produced by private companies are protected by legislation. Thus seed produced by contract in the region is exported for processing and packaging, and re-imported for production. The few varieties developed by public institutions (especially in Kenya) are often susceptible to diseases and pests. Very little has been done to develop improved snap bean varieties freely accessible to smallholder farmers and informal seed producers (who supply over 90% of dry bean seed grown in the region) in the region. Due to the high quality demands, smallholder farmers rely on fungicides and insecticides to reduce production and post harvest losses associated with diseases and pests. This is no longer a viable option because recently instituted minimum residue levels, and preference by importers to source produce from large scale producers threaten to push smallholder farmers out of business (Kimani, 2005; CIAT, 2004). In East and Central Africa, production is based on determinate types. Unlike their counterparts in South America, East African farmers normally do not grow the indeterminate types, which are higher yielding and have longer harvest duration. Breeding for high yield, disease and pest resistance, tolerance to abiotic stresses, general adaptation to tropical conditions and acceptable market quality is a critical component of an integrated strategy to address constraints to snap bean production in the region. Unlike snap beans, the main constraint to snap runner bean production is requirement for extended light. Current varieties are long day. They require at least three hours of additional lighting to stimulate flowering and pod setting. This demands installation of expensive infrastructure in production fields. Consequently, only large commercial firms can produce and market this high value crop. Runner beans are generally more resistant to major bean diseases and have been proposed as possible source of resistance to common bean. Development of short day runner beans will facilitate smallholder farmers to gainfully participate in runner bean sub-sector and also reduce production costs and make local produce more competitive in international markets. A regional program was therefore started in 2006 to support the development of improved snap bean varieties with high yield potential, resistance to biotic stresses and consumer preferred pod quality, and short-day runner beans for smallholder production. This report highlights progress in this program.

Materials and Methods: The regional snap bean program is based at six institutions in four countries, Uganda, Kenya, Rwanda and Tanzania. In Uganda, snap bean research is based at National Crops Resources Research Institute (NACRRI), which has been coordinating the program since 2006. In Rwanda activities are based at ISAR station in Rubona. In Kenya, the national snap bean program in coordinated by the University of Nairobi with activities at National Horticultural Research Centre at KARI-Thika and at Moi University in Eldoret. In Tanzania, snap bean research is based at Selian Agricultural Research Institute (SARI), Arusha. Work at Kawanda has focused on screening snap bean varieties with farmers and developing production packages. At Moi University, crosses were made to develop locally adapted snap bean cultivars with improved pod yield, resistance to anthracnose and rust, and marketable pod quality (van Rheenen et al., 2003). After six generations of selection, 23 lines were identified. Following preliminary evaluations, the number of lines was reduced to 12. The 12 lines were evaluated in national performance trials at six locations (Eldoret, Thika, Kakamega, Marigat, Lanet and Njoro) in collaboration with Kenya Plant Health Inspectorate (KEPHIS) which coordinates testing of candidate varieties from public and private breeders and formal release of the best varieties. The trial included three commercial cultivars as checks. At the University of Nairobi, activities have focused on development of regional nurseries of bush and climbing snap beans, development of crosses to transfer rust, anthracnose, angular leaf spot, root rots and anthracnose resistance to popular commercial varieties, and breeding short day snap runner beans.

Snap bean is a relatively new sub-sector in Tanzania. Activities at Selian, therefore focused on a baseline survey to better understand the major constraints and the production and marketing environment, evaluation local bush lines and 35 advanced climbing bean lines from CIAT, development of agronomic and crop protection management practises. In Rwanda, focus has been on evaluation of 40 advanced climbing and 18 bush snap lines received from CIAT, Colombia and selection for pod characteristics, (colour, shape, texture and taste) and resistance to rust, angular leaf spot and anthracnose from local variety ‘Vunikingi’ and its crosses with bush snap beans.

Results and Discussion: In Uganda, 11 lines introduced from CIAT and Kenya were evaluated for three seasons. Paulista and Helda were used as checks. Major constraints were rust, angular leaf spot and common bacterial blight. However, field surveys showed that rust was most limiting in farmers’ fields. Results showed that pod inoculation was most effective for screening for resistance to common bacterial blight. Six lines (HAB 433, BC 4.8, A 20, J 12, L1 and L 12) showed combined tolerance to the three major diseases (Table 110). Line HAB 433 was selected on-farm for yield and quality (pod size and shape, length, snappiness and taste).

Table 110. Disease scores of 11 snap bean lines at Namulonge, Uganda.

Line	Common bacterial blight	Rust	Angular leaf spot
HAB 173	4	5	2
HAB 414	7	5	3
HAB 433	2	2	4
A20	3	3	3
K3	4	6	3
L1	4	5	3
L12	4	5	3
J12	4	5	-
BC4.5	6	6	3
BC 4.8	5	3	7
BC 7.5	5	6	5
Paulista	6	8	7
Helda	7	8	6

Twenty-one F_6 climbing bean lines introduced from Rwanda, 14 commercial varieties of European origin and 35 F_5 climbing bean lines from CIAT were sown in an observation nursery at Kawanda. A survey of economic pests in farmers' fields in Uganda showed that bean aphids, pod borers and bean fly were the most important insect pests in the surveyed locations, while bean leaf rust, root rot and angular leaf spot are the most important diseases. All farmers interviewed invariably use pesticides in their fields to control the pests and diseases. Results showed that application of inorganic and organic fertilizers increased pod yield from 6.8 t ha^{-1} to 7.4 t ha^{-1}. Paulista and Teresa were the best yielding commercial varieties with yields of 8.3 and 8.9 t ha^{-1}, respectively.

In Rwanda, five F_6 lines were selected from Vunikingi x Amy populations. Yield of 58 lines introduced from CIAT and local collections varied from 5 to 12 t ha^{-1}. As expected climbers were better yielding compared to bush varieties. The most promising lines were Boon, Cabbra, G685, Ncekarkonnigia, Saxa, Khaki and Loiret.

Survey results showed that major constraints to snap bean production in Rwanda were diseases, pests and weeds. Major diseases included root rots, angular leaf spot, rust and bean common mosaic virus. The main pests are aphids, bean stem maggot, spider mites and crickets. Major weed species were *Commelina spp, Digitaria spp, Bidens spp,* and *Oxalis specie.* Diseases were controlled with a range of fungicides. Evaluation of commercial varieties and introductions for reaction to diseases showed that Tarrot was susceptible to rust, Saxa and Cabbra to anthracnose and *Ncekarkonnigia* to BCMV. In Tanzania, 35 climbing bean lines from CIAT and 5 local bush varieties were sown in observation nursery and to increase seed at Madiira.

In Kenya, three snap bean accessions were collected from farmers' fields in Murang'a district, five from KARI-Thika and three from Madagascar. These were added to the working collection at the University of Nairobi. Thirty-three bush and seven climbing bean lines were sown in observation nurseries and seed increase plots at Mwea and Kabete. One pre-release variety and 12 rust resistant advanced lines were selected at Thika. Thirty four new crosses were made to transfer resistance to root rots, angular leaf spot and common bacterial blight to susceptible commercial varieties (Paulista, Amy, Julia, Teresa, Vernadon, Morgan, Alexandria, Kutuless and Morelli). Sources of resistance included Beldakmi and Beltglade lines with *ur* genes and L227 which has multiple resistance to root rots, angular leaf spot, rust and common bacterial blight. F_1's were advanced to F_2.

The characteristics of the 12 lines selected at Moi University in the national performance trials at six locations are presented in Table 111. Flowering was earliest at Thika (37 days) and latest at Njoro (50 days). Duration to first picking was shortest at Thika (56 days) and longest at Njoro (62 days). Picking period varied from 22.6 days at Marigat to 36 days at Njoro and 40 days at Thika. On an average, Lanet and Njoro showed better pod quality scores than Marigat and Eldoret. The pod quality at latter location was poorest, probably due to the poor plant growth in general. The interaction between locations x trial entry was highly significant, suggesting that different entries respond differently to environmental conditions in respect of pod quality. The variety differences for reaction to rust were significant. The entry with the severest symptoms was No. 1, showing a mean score of 7.6. It differed significantly from those that had a score of 6.6 or less. Entry No. 7 had the lowest rust score of 1.2, differing significantly from those having a score of 2.2 or more. On an average, Marigat showed significantly more severe rust symptoms than other locations. The interaction between location x entry was significant, suggesting that possible differences in rust races occur. Variety differences for fresh pod yield were significant. The entry with the lowest yield was No. 3 with an average of 9.6 t ha^{-1}, followed by No.1 with 9.7 t ha^{-1}. These differed only significantly from those that had 12 t ha^{-1} or more. Entry No. 11 had the highest yield of 13.1 t ha^{-1}, differing significantly from those having a yield of 11 t ha^{-1} or less. The locations differed significantly pair-wise: Marigat and Njoro had the highest yields; Lanet and Kakamega were intermediate, and Eldoret and Thika lowest. The mean yields per location ranged from 3.1 t per ha^{-1} at Thika to 19.7 t ha^{-1} at Marigat. No significant interaction between location and trial entry was observed which indicates that varieties had no differential response to environment. It suggests that the yield adaptation of the entries to different environments was similar.

Table 111. Days to flowering, first and last day of pod picking, pod quality, rust score and fresh pod yield of snap bean lines selected at Moi University, Eldoret, Kenya

*Line	Days to 50% flowering	Days to first pod picking	Days to last pod picking	**Pod quality	***Rust score	Fresh Pod yield t ha^{-1}
1	45.1	59.0	89.7	3.8	7.6	9.7
2	43.5	57.1	89.7	3.3	4.6	11.4
3	43.6	57.2	88.9	3.6	2.4	9.6
4	44.8	57.3	89.2	2.3	2.1	12.9
5	43.0	58.1	89.2	3.1	2.1	11.7
6	42.6	56.6	89.4	3.9	6.4	10.6
7	46.1	58.9	89.8	4.0	1.2	12.2
8	43.6	56.7	89.8	3.5	2.3	13.0
9	43.0	56.9	89.3	3.7	4.2	10.3
10	44.4	57.3	89.4	3.9	2.3	11.2
11	45.5	56.8	89.4	2.7	2.0	13.1
12	43.8	59.1	89.4	3.8	4.3	10.3
Mean	44.1	57.6	89.5	3.5	3.5	11.3
CV (%)	6.7	3.57	1.52	12.7	28.7	28.9
LSD .05	1.94	1.35	NS	0.36	0.94	2.2

* Lines 1, 4, 7 and 11 were checks

* Pod quality on a scale of 1= best and 5=worst.

** Rust on CIAT scale, 1-3 =resistant, 4-6= intermediate and 7-9=susceptible at three locations- Marigat, Lanet and Njoro.

At Kabete, five F_3 populations were developed from crosses between a long-day commercial runner snap variety and five short day dry grain type, short-day varieties. The F_3 progenies were advanced to F_4 and F_5 generations at Ol Jorok and Laikipia. Pod set and pod characteristics were the main selection criteria under short day conditions. The population showed considerable segregation for pod traits. Progenies were grouped into six categories (Table 112). Long, straight pods are preferred by exporters. Curved short pods are associated with local short day parental genotypes. F_5 lines showed heavy podding at Ol Jorok during the 2008 cropping season. Two to three harvests were made from most of the lines. Runner bean lines showed high levels of resistance to angular leaf spot, root rot, common bacterial blight, anthracnose and frost despite heavy disease pressure which caused severe damage to climbing and bush bean lines in adjacent plots. However, some runner bean lines showed intermediate reactions to rust infection.

Table 112. Classification of F_4 and F_5 runner bean lines based on pod characteristics at Ol Jorok and Laikipia.

Pod category	Number of lines
Long straight	19
Medium straight	18
Short straight	14
Long curved	30
Medium curved	28
Short curved	26

Conclusion: Although breeding snap beans in eastern Africa is still in the early stages, considerable progress has been made in developing new lines of snap with resistance to major biotic stresses and short-day runner beans in eastern Africa. More than 20 promising bush and climbing snap beans have been selected in preliminary trials from advanced lines and segregating populations. For most of the countries, breeding snap beans is a new but promising innovation. This program was supported by CIAT/PABRA and ASARECA. However, it was temporarily suspended for the last two years due to re-organisation of ASARECA. The program is now expected to re-start late in 2009. Nineteen F_5 lines of runner beans with preferred long pods and good pod set under short day conditions were selected.

Contributors: Paul Kimani, Steve Beebe (CIAT), Michael Ugen (Uganda), Augustine Musoni (Rwanda), Festo Ngulu (Tanzania), van Rheenen, George Chemining'wa, John Nderitu and Agnes Ndegwa (Kenya).

Collaborators: Bean programs at Namulonge (Uganda), SARI, Arusha (Tanzania), University of Nairobi, Moi University and KARI-Thika (Kenya) and ISAR, Rubona (Rwanda), CIAT Bean Program, Cali (Colombia).

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Kimani, P.M. 2006. Snap beans for income generation by small farmers in East Africa [On line]. Internacional de Agricultura Tropical (CIAT), Kampala, Uganda. 2p. Highlights: CIAT in Africa No.31.

Van Rheenen, H.A., Odindo, A.O. and Iruria, D.M. 2003. Anticipated promises and problems for snap bean seed production in Kenya. Proceedings of the workshop on "The seed industry in Kenya at crossroads" held at Nakuru, Kenya from 1st – 3rd July, 2002.

Product 4: Strengthened institutions that enhance bean product development and delivery

Activity 4.1 Strengthened capacity of NARS: increasing the knowledge and skills of scientists and staff from NARIs, NGOs and Rural Service Providers

Highlights:

- A total of forty-nine students conducted research activities related to their thesis work, of which twenty eight were at CIAT HQ, and twenty one in Africa. Of these, three PhD and one MSc students were as visiting researchers at HQ.
- In Latin America, two M.Sc. candidates, and two pre-graduate students completed their research theses. In Africa three PhD, four M.Sc. and one Bs. candidates completed their research theses.
- A total of thirty-three students continue their studies, as follows: six Ph.D. candidates in Africa and five in Latin America, eight M.Sc. candidates in Africa and four in Latin America, and ten pre-graduate in Latin America.
- Twelve visiting researchers coming from Colombia, Cuba, Denmark, Guatemala, Hungary, India, Panama and Zambia received training in different disciplines at headquarters.
- Several courses and workshops were held in Latin America and Africa
- During this reporting period there was a joint stakeholders meeting for PABRA partners, as well as a joint steering committee meeting for SABRN and ECABREN where they reflected on the progress over the past 4 years, and planned activities to achieve the milestones contributing towards achieving the goals in the final year of the project, as well as to plan for the next phase.
- A number of students have either registered or started their course work at various universities to sharpen their knowledge and skills in bean research for development. Two new students doing MSc in plant breeding enrolled at the University of Zambia and Penn State University, both from Malawi. Two other students had been accepted for Ph.D. programs at the University of Free State and Massey University – New Zealand. These scientists will add to the existing capacity for bean research in the region.

4.1.1 Degree and non-degree training in Latin America

Students:

Name	Degree	Status	University	Title
Ph.D. Candidates				
Asrat Asfaw Amele	Ph.D.	Visiting student	Wageningen University, Netherlands (M. Blair and I.M. Rao)	Genetic investigation of drought tolerance in common beans for Ethiopia and the ECABREN region
Louis Butare, ISAR-Rubona	Ph.D.	Continuing	Gembloux Agricultural University, Belgium. (S. Beebe, I.M. Rao and M. Blair)	Root development and root health of interspecific progeny of crosses between *P. vulgaris* and *P. coccineus*
Luz Nayibe Garzón	Ph.D.	Continuing	Universidad Nacional de Colombia, Bogota (M.Blair and G. Ligarreto)	Anthracnose resistance
Homar Gill	Ph.D.	Visiting student	Universidad de Tamauliplas, Mexico (M. Blair)	Research on bean diversity

Name	Degree	Status	University	Title
Lara Ramaekers	Ph.D.	Continuing	University of Leuven, Belgium (M. Blair and I.M. Rao)	Biological nitrogen fixation
Gloria Santana, CORPOICA	Ph.D.	Continuing	Universidad Nacional de Colombia, Palmira. (M. Blair, F. Morales and G. Ligarreto)	Resistance to bean common mosaic virus
Assefa Teshale Mamo	Ph.D.	Visiting student	University of Padua, Italy (S. Beebe, M. Blair and J.M. Bueno)	Conducting researching in bruchid resistance, drought tolerance and canning quality
León Darío Vélez	Ph.D.	Continuing	Universidad Nacional de Colombia, Bogotá. (M. Blair and G. Ligarreto)	Inheritance of intercropping ability between common bean and maize
M.Sc. Candidates				
Juana Marcela Cordoba	M.Sc.	Continuing	Universidad Nacional, Bogotá (M. Blair)	SSR development and mapping
Leonardo Duque	M.Sc.	Continuing	Universidad del Valle, Cali, Colombia (J.M. Bueno and S. Beebe)	Evaluation of the use of the oil of limoncillo to repel *Bemicia tabaci* in bean
Victor Mayor Durán	M.Sc.	Continuing	Universidad. Nacional, Palmira	Drought tolerance
Hanny El Sadr	M.Sc.	Visiting student	University of Saskatchewan (M. Blair)	Tannin accumulation in seed coats
Orlando Grijalba	M. Sc.	Continuing	Universidad del Valle, Cali, Colombia (J.M. Bueno)	Development of action thresholds for rational control of *Bemisia tabaci* biotype B as a pest of sweet pepper
Hugo Arley Jaimes	M.Sc.	Completed	Universidad Nacional de Colombia, Palmira (J.M. Bueno)	Evaluation of bean interspecific hybrids for resistance to *Acanthoscelides obtectus*
Lizzie Kalalokesya	M.Sc.	Visiting student	University of Zambia	Studying CBB Resistance breeding in Andean Bean Crosses
Paola Sotelo	M.Sc.	Completed	Universidad Nacional de Colombia, Palmira (J.M. Bueno)	Inheritance of resistance to bean leaf crumple virus in snap beans
Pregraduate students:				
Alejandro Chaves	B.Sc.	Completed	Universidad Javeriana Bogotá (J.D. Palacio and M. Blair	Diversity analysis of snap beans
Aura Marina Díaz Bravo	B.Sc.	Completed	Universidad del Valle (M. Blair)	HPLC analysis of phytate concentration in common bean
Andrea Carolina Fernandez	B.Sc.	Continuing	Universidad Javeriana, Bogotá (M. Blair)	Drought candidate genes for common bean

Name	Degree	Status	University	Title
Claudia Marcela Franco	B.Sc.	Continuing	Universidad del Valle (M. Blair)	SSR mapping
Andrea Lorena Herrera	B.Sc.	Continuing	Universidad de Antioquia (M. Blair)	Tannin evaluation in common bean
Natalia Hurtado	B.Sc.	Continuing	Universidad Javeriana (M. Blair)	SSR mapping
Paulo Izquierdo	B.Sc.	Continuing	Universidad de Tolima (M. Blair)	NIRs analysis of common bean nutritional quality
María Alejandra Lozano	B.Sc.	Continuing	Universidad del Valle (M. Blair)	HPLC analysis of tannin concentration in bean seed coats
Fredy Monserrate	B.Sc.	Completed	Universidad Nacional, Bogotá (G. Hyman and M. Blair)	Stability analysis of biofortified common bean lines
Juan Carlos Perez	B.Sc.	Continuing	Universidad Nacional, Palmira (M. Blair and I.M. Rao)	Drought tolerance in common bean
Alvaro Soler Garzón	B.Sc.	Continuing	Universidad del Tolima	Genetic diversity of wild core collection of common bean analyzed through fluorescent microsatellites
Marina Villacís	B.Sc.	Continuing	Universidad del Valle (M. Blair)	SNP mapping

Non-degree training of visiting researchers:

Name	Staff	Dates	Institution	Topic
Orlando Chaveco	S. Beebe	August-September	Unidad de Extensión, Investigación y Capacitación Agropecuaria de Holguín, Cuba	Testing materials with high content of iron and zinc and materials tolerant to drought
Cristina Cvitanich	M. Blair	May	Institute of Molecular Biology, University of Aarhus	Nutrition project
Carmen Iliescu	M. Blair	June	Agricultural Biotechnology Center, Godollo, Hungary	Evaluation of common bean diversity in Eastern Europe and collaboration on SNP detection
Lizzie Kalalokesya	M. Blair	September-November	University of Zambia	Marker Assisted Selection of VAX-derived CBB Resistance in Andean bean crosses
Juliana Ines Medina	M. Blair	June-August	Colciencias	Positional cloning of the genomic region involved in multiple virus resistance based on the map of *Phaseolus vulgaris*
Audino Melgar	M. Blair, S. Beebe	November	IDIAP, Panama	Training on nutritional analysis of common bean

Name	Staff	Dates	Institution	Topic
Natalia Moreno	M. Blair	January-December	Colciencias	Nutritional quality and diversity of Eastern and Southern African common bean varieties
Peter Papp	M. Blair	April	Agricultural Biotechnology Center, Godollo, Hungary	Evaluation of common bean diversity in Eastern Europe
Elena Perez Vega	D. Debouck Pathology	November	Servicio Regional de Investigación y Desarrollo Agroalimentario, SERIDA, Asturias, Spain	Germplasm management; *Xanthomonas* sp inoculation
Karla Ponciano	M. Blair	July	ICTA, Guatemala	Training on drought
Emigdio Rodriguez	M. Blair, S. Beebe	November	IDIAP, Panama	Training on nutritional analysis of common bean
Prem Nath Sharma	M. Blair	October-March 2009	Hillside Agricultural Research Center	Evaluation of common bean diversity in India

Courses and Workshops:

Date	Title	Duration (days)	Total No. participants	No. of female participants	No. of CIAT instructors
3-28 March	Training course on phenotyping of the Tropical Legumes Project, ICRISAT, Hyderbad, India (TLI)	25	30		2
25 April	Bruchids	1	15	12	1
8 May	Sampling and identification of whiteflies	5	2	0	3
16 May	Insecticide resistance in whiteflies	1	15	12	1
23 May	Varietal resistance to insects	1	15	12	1
23 May	Sampling methods in bean pests	1	15	12	1
12 June	Training in mass rearing methods	1	1	0	2
14 July	Pest of beans their control	1	20	5	1
16 July	Whitefly mass rearing methods	2	1	1	3
20 Aug.	Whitefly insecticide resistance	3	1	1	3
2 Sept.	Control of bean insect pests	1	15	5	1
6-10 Sept.	CYTED funded project workshop on progress in developing transgenic maize and common bean tolerant to drought	3	12	5	1

4.1.2 Degree and non-degree training in Africa

Name	Degree	Status	University	Title
Ph.D. Candidates				
Isaac Fandika	Ph.D.	Accepted	Massey University, New Zealand	To be decided
Virginia Gichuru	Ph.D.	Completed	Makerere University, Kampala, Uganda	Symptomatology and characterisation of *Pythium* spp. of major crops in a bean based cropping system in south-western Uganda
Godwill Makunde	Ph.D.	Registered	University of Free State, South Africa	Association mapping to quantify genetic diversity in drought adaptation of common bean
Firew Mekbib	Ph.D.	To defend April 2009	Norwegian University of Life Sciences	Genetic enhancement of sorghum diversity through an integrated approach.
Clare Mukankusi	Ph.D.	Completed	University of KwaZulu-Natal,RSA	Breeding beans (*Phaseolus vulgaris* L) for resistance to Fusarium root rot (*Fusarium solani f.sp. phaseoli*) and large seed size in Uganda
John Muthamia	Ph.D.	Continuing	University of Leuven	Quantification of the agronomic contribution of the various Plant Growth Promoting Rhizobacteria (PGPR) and VAM singly and in combination on selected bush bean and climbing bean varieties
John Nzungize	Ph.D.	Continuing	Gembloux Agricultural University	Evaluation of the genetic diversity of the isolates of *Pythium* spp. in Rwanda for a selection of the varieties of common bean for resistance to the root rot caused by *Pythium* spp
Bernard Okonda	Ph.D.	Continuing	University of Nairobi	Genetic variation for nitrogen fixation, micronutrient density and influence of plant growth promoting rhizobacteria in common
M.Sc. Candidates				
Musoni Augustine	M.Sc.	Completed	University of Nairobi	Inheritance of fusarium wilt (*F. oxysporum f.sp. phaseoli*) and selection for multiple disease resistant and marketable climbing bean varieties
Steven Buah	M.Sc.	Continuing	Makerere University, Kampala, Uganda	Phenological and pathogenic characterization of bean landraces from South West Uganda
Virginia Chisale	M.Sc.	Started	Penn State University - USA	To be decided
Lizzie Kalolokesya	M.Sc.	Started	University of Zambia	Use of SCAR marker SU91 in marker assisted selection (MAS) for common bacterial blight (CBB) resistance in common bean

Name	Degree	Status	University	Title
Kanyenga Lubobo	M.Sc.	Continuing	Lubumbashi University, DRC	Breeding for bean root rots resistance in southern midland of D. R. Congo
Francoise Murorunkwere	M.Sc.	Submitted	Makerere University, Kampala, Uganda	Improving resistance to bean common mosaic virus and bean common mosaic necrotic virus in common bean using marker assisted selection
Jasper Mwesigwa	M.Sc.	Completed	Makerere	Characterization of races of *C. lindemuthianum i*n Uganda.
Pheonah Nabukalu	M.Sc.	Completed	Makerere University, Kampala, Uganda	Improving resistance to anthracnose in commercial verities in Uganda using marker assisted selection
Joseph Orede	M.Sc.	Continuing	University of Nairobi	Breeding for common bean for disease resistance through gene pyramiding and phenotyping
Bello Shano	M.Sc.	Continuing	University of Malawi	Evaluation of common bean genotypes for Al and drought resistance
Geoffrey Wachira	M.Sc.	Continuing	University of Nairobi	Screening common bean cultivars for resistance to bean fly
Felix Waweru	M.Sc.	Continuing	University of Nairobi	Drought phenotyping in RILs, reference collection and regional bean varieties
Pregraduate students:				
Mackford Maseko	Dip. Agric.	Completed	Natural Resources College; Malawi	

Non-degree training of visiting researchers:

Name	Staff	Institution	Topic
Esther Arunga,	Uganda	Moi University, Kenya	Bean pathology research methods and biotechnology
Tarcisis Mutuoki	Enid Katungi	KARI-Katumani	Socio-economist, integrated into activities for mentoring, leading the market studies in eastern Kenya
Yiteye Abebe	Enid Katungi	Melkassa	Socio-economist, integrated into activities for mentoring, completion of data cleaning for Ethiopia

Training Courses and Workshops:

Date	Title	Duration (days)	Total No. participants	No. Women participants	No. of CIAT instructors	No. of NARS instructors
9 Jan	PABRA quarterly meeting Kampala, Uganda	1	8	3	-	-
14-15 Jan	TL II Drought Project Bean and Chickpea Planning Meeting. Nazret Ethiopia					
17–18 Jan	Planning workshop for the Bean Drought Project for partners from Central and South Rift Valley, Nyanza and Western Kenya Machakos Kenya	3	14	3	2	3
16 - 19 Jan	TL II Training workshop on drought phenotyping at KARI-Katumani, Machakos, Kenya	4	15	3	3	
20 – 24 Jan	PABRA Stakeholders workshop Kampala, Kenya	5	43	12	3	
14 - 15 Feb	Participatory Internal Control System and Participatory Monitoring and Evaluation Training					
18 Feb	PABRA-CIAT-LAGROTECH Nutrition and Health Training workshop for Trainers in Kisumu, western Kenya		43	17	1	
26-29 Feb	CEDO Nutrition Training of Trainers with Support from CIAT, Masaka, Uganda		30	13	0	
26 Febr	Evaluation of PABRA Capacity Building Programme Arusha, Tanzania	1	26	8	2	
27 Febr	PABRA Monitoring and Evaluation Arusha, Tanzania	1	21	7	2	
28 Feb	Tropical Legumes II - Nangina Social Work Project 2 - Training of Trainers (to build capacity of trainers on basic principles of bean seed production & maintenance of sustainable bean seed systems) Mumias, Kenya		15	5	1	
Feb - March	Training of Trainers (Extension staff from partner organizations in Kenya) on seed production, post harvest management and seed management		147	52	0	3
4 - 8 March	Training Course on the use of ECOSAUT: A Model for Economic, Social and Environmental Evaluation of Land Use Alternatives, Harare, Zimbabwe		19	0	1	

Date	Title	Duration (days)	Total No. participants	No. Women participants	No. of CIAT instructors	No. of NARS instructors
7 - 8 March	Capacity Building Evaluation of the Participatory Plant Breeding-Participatory Variety Selection (PPB-PVS), Mbeya, Tanzania	2	24	7	2	
March	Bean seed system planning workshops in Central Rift Valley of Ethiopia, Southern Ethiopia, North west Ethiopia, East Ethiopia	7	132	10	1	5
March–Oct	Bean seed production/supply, field data collection (seed production and supply/use)		1670	791	0	1
17-20 March	PABRA Steering Committee meeting, Lusaka, Zambia	4	20	4	-	
25 March	Bean Drought Project Partners' Meeting Tropical Legume II for Central Rift Valley, Nazereth, Ethiopia	1	33	0	1	
27 March	Bean Drought Project Partners' Meeting Tropical Legume II Southern Regions, Awassa, Ethiopia	1	43	0	1	
29 March	Bean Drought Project Partners' Meeting Tropical Legume II North-East Regions, Debre Brehan, Ethiopia	1	16	0	1	
14 April	Bean Drought Project Partners' Meeting Tropical Legume II for West Haraghee, Ethiopia	1	16		1	
17 April	Bean Drought Project Partners' Meeting Tropical Legume II Southern Regions, Dire Dawa, Ethiopia	1	17		1	
18 April	PABRA Capacity Building Evaluation – Participatory and Monitoring Evaluation, Kakamega, Kenya	1	27	1	1	
19 April	Evaluation of PABRA Capacity Building PPB-PVS, Kakamega, Kenya	1	9	1	1	
30 April- 1 May	Developing Participatory Monitoring and Evaluation Framework, Uganda	2	29			
5-16 May	Training course on breeding and physiology of drought resistance in common bean (TLII project)	12	24	5	5	
14 May	Seed Aid for Seed Security: Outreach Meeting in Norway	1				
22-23 May	TLII Cross-Crop Seed Systems Meeting Nairobi, Kenya	2				
26-28 May	Participatory Variety Selection (associated with McKnight and BMZ Projects)	3	28	8	3	0

Date	Title	Duration (days)	Total No. participants	No. Women participants	No. of CIAT instructors	No. of NARS instructors
28-30 May	Participatory Variety selection (Malawi)	3	29	5	3	
29 – 31 May	McKnight Beans Seed Systems: yearly Planning Meeting: Lilongwe, Malawi	3				
8-12 June	Organizing and conducting focus group Household questionnaire, the art of interviewing and establishing rapport	5	7	3	1	2
July	Organizing and conducting focus group revisited	1	7	3	1	3
August	Household questionnaire, the art of interviewing and establishing rapport	3	14	3	1	2
4-5 Sept	Review workshops for Bean Drought Project TL II Seed System for partners from Central South rift valley and Nyanza and western Nakuru, Kenya	2	29	3	1	3
11–12 Sept	TL II Bean Seed Systems Review Meeting, Kisumu, Kenya	2	17	3	1	
18-19 Sept	Bean seed systems inception and planning meeting, Machakos, Kenya	2	33	6	2	4
21-25 Sept	Participatory Plant Breeding and Participatory Variety selection (Training of Trainers), Ethiopia	5	24	5	2	
22-23 Sept	Planning Workshop for Bean Drought Project for Central and eastern Kenya, Machakos, Kenya	2	28	7	1	4
22-26 Sept	Participatory Plant Breeding: Training of Trainers (ToT) Course	5	23	5	3	0
29 Sep- 4 Oct	TLII Drought Project : Annual Meeting, full project, Addis Ababa, Ethiopia	7				
28 – 30 Oct	Participatory Variety selection, Mozambique	3	19	2	1	1
5 Nov	Seed Security: linking formal and informal sectors, Accra, Ghana	1				
2 – 3 Dec	TL II Bean Seed System Year II Planning Workshop. Adama, Ethiopia	2	42		2	
2 - 3 Dec	TL II Bean Drought Project Partners Meeting Nazret, Ethiopia	2				
5 – 6 Dec	TL II Bean Drought Project Partners Meeting- SARI, Awassa, Ethiopia	2				
10-12 Dec	Household questionnaire, the art of interviewing and establishing rapport	3	9	0	1	2
13 Dec.	Market surveys	1	2	0	1	0
14-15 Dec	Market surveys	2	7	1	1	0

4.1.3 Trips and attendance of Headquarters staff at meetings

The Mesoamerican bean breeder and project manager visited the following countries:

Date	Destination	Event or purpose
11-13 April	Costa Rica	LIV PCCMCA meeting and Agro-Salud Workshop
07-11 May	Malawi	Breeding for Drought Workshop
21-25 My	Celaya, Guanajuato, Mexico	Internacional Bean Congress
29 June-05 July	Dakar, Senegal	TL1 Annual Meeting
06-08 July	Nairobi	TL2 visit to field sites
11-15 Aug	Austria, Vienna	HarvestPlus Workshop
27 Sept – 5 Oct	Ethiopia	TL2 Project meeting
5-8 Oct	Bukavu, Dem. Rep. Congo	Harvest Plus planning meeting
9-11 Oct	Butare, Rwanda	Harvest Plus planning meeting
11-13 Oct	Tanzania	Review of progress in selection of drought tolerant beans
02-05 Dec	Nicaragua	Review and evaluation of drought trials

The Andean breeder/germplasm specialist visited the following countries:

Date	Destination	Event or purpose
11-17 Jan	San Diego, California	Plant and Animal Genome – presentation of GCP results.
21-26 Jan	Chillán, Chile	collaboration with INIA on diversity assessment of Chilean landraces.
21-25 May	Celaya, Mexico	Congreso Nacional de Frijol – presentation on marker assisted selection for breeding/producer audience
8-12 Sept	Hyderabad, India	coordination with ADOC sequencing project
15-20 Sept	Bangkok, Thailand	GCP annual meeting – presentation of results of TL1 project
29 Sept-3 Oct	Addis Ababa, Ethiopia	TL2 coordination meeting
5-8 Oct	Bukavu, Dem. Rep. Congo	Harvest Plus planning meeting
9-13 Oct	Butare, Rwanda	Harvest Plus planning meeting
20-25 Oct	Campinas, Brazil	Congresso Nacional de Pesquisa de Feijão – presentation on bean genomics
7-12 Dec	Vallarta, Mexico	International Congress on Legume Genetics and Genomics – presentation on diversity of common bean

The plant nutritionist:

Date	Destination	Event or purpose
17-29 March	ICRISAT-Patancheru, India	Training course on phenotyping of the tropical legumes Project (TLI)-Participated as an instructor
11-13 March	Pennsylvania State University, USA	WUN workshop on abiotic stress factors
2-10 May	Lilongwe, Malawi	Training course on breeding and physiology of drought resistance in common bean (TLII project)
6-10 Sept	Granada, Spain	CYTED funded project workshop on progress in developing transgenic maize and common bean tolerant to drought

Awards:

- The 2008 CIAT Scientific Poster Award-Second Place
  Physiological evaluation of drought resistance in elite lines of common bean (*Phaseolus vulgaris* L.) under field conditions. J. A. Polanía, M. Grajales, C. Cajiao, R. García, J. Ricaurte, S. Beebe and I. M. Rao
- Annual Conference of Plant Nutrition Society of Germany-Scientific Poster Award-Second Place
  The interaction between aluminum toxicity and drought stress in common bean (*Phaseolus vulgaris* L.). Z. B. Yang, D. Eticha, I. M. Rao and W. Horst

4.1.4 Trips and attendance of African staff at meetings

The Plant Pathologist/PABRA Coordinator:

Date	Destination	Event or purpose
21-25 Jan	Kampala, Uganda	PABRA Stakeholders Meeting
28 Jan	Nairobi, Kenya	Coordination TSBF
10-14 Febr	Gisenyi, Rwanda	Design and PM&E Meeting of LK-PLS (SSACP)
21-22 Febr	Aleppo, Syria	System Wide IPM Meeting
24 Febr	Arusha, Tanzania	Visit with Albin
5-6 March	Nairobi, Kenya	Visit With Albin
18-20 March	Kampala, Uganda	Kirkhouse meeting
16-20 March	Lusaka, Zambia	PABRA SC meeting
4-12 April	Cali, Colombia	Knowledge sharing week
2 May	Nairobi, Kenya	Coordination (TSBF)
5-6 May	Rwanda	Coordination (MINAGRI, ISAR, USAID, CIAT)
21- 23 May	Nairobi, Kenya	TLII Meeting
26-31 May	Japan	Visit JIRCAS, JICA and TICADIV meeting
11-12 June	Arusha, Tanzania	Coordination
17-19 June	Kakamega, Kenya	CRSP Project Planning Meeting
30 June – 4 July	Lausanne, Switzerland	Fourth CGIAR Senior Leadership Program
8 July – 15 Aug	Kenya	Home Leave
26-30 July	Minneapolis	APS Meeting
2-4 Sept	Accra, Ghana	CGIAR-FARA Partnership Meeting
27 Sept - 4 Oct	Ethiopia	Tropical Legumes II
8-10 Oct	Rwanda	LKPLS Planning Meeting
Nov	Burundi	ISABU Planning
7-22 Dec	Cali, Colombia	BoT meeting

The SABRN Coordinator/Breeder:

Date	Destination	Event or purpose
15-20 Jan	Kampala	PABRA Stakeholders Meeting
29 Feb – 04 Mar	Barcelona	Legumes CRSP inception meeting
06 Mar	Kampala	Kirk House Trust proposal development on use MAS in beans
5-13 Apr	Cali	CIAT Annual review meetings
16-18 June	Nairobi	AGRA Soil Health program inception meeting
29 Jun – 5 July	Dakar	TL-1 annual review meeting in Senegal
5-10 Oct	Maputo	McKnight CoP annual meeting in Mozambique
25-27 Oct	Harare	Follow up on TL-1 and TL-2 agreements in Zimbabwe
27 Oct – 4 Nov	Johannesburg	Follow up on H+ activities in South Africa
15-20 Nov	Luanda	Follow up on bean research activities in Angola
20-25 Nov	Harare	Join the CIAT team during a visit by Dr Pachico to southern Africa

The ECABREN Breeder:

Date	Destination	Event or purpose
8-10 Jan	Kampala, Uganda	PABRA Quarterly Planning meeting
13-16 Jan	Melkassa, Ethiopia	TLII planning meeting
17-19 Jan	Katumani, Kenya	Drought phenotyping training workshop
20-26 Jan	Kampala, Uganda	PABRA stakeholders workshop
23-24 Febr	Kabete, Thika and Kiboko	TL II field sites characterisation with CIAT consultant
5-7 March	Kampala, Uganda-	KT project planning and proposal review workshop
11-13 March	Kampala, Uganda	PABRA quarterly planning workshop
4-14 April	Cali, Colombia	Annual knowledge sharing week
5-11 May	in Lilongwe, Malawi	
30 June- 6 July	Dakar, Senegal	TL I annual review and planning workshop
7-8 July	Katumani, Kenya	Field visits to TL 2 regional nursery
25 July-5 Aug	Katumani, Embu, Meru, Njoro, Narok, Kisumu, Eldoret, Kakamega and Kitale (Kenya)	National performance trials technical committee monitoring tour in Coast, Central, Eastern, Rift Valley, Nyanza and Western provinces
24-27 Aug	Thika, Kenya	Nutribean Review and Planning workshop
7-11 Sept	Kampala, Uganda	PABRA proposal finalization and planning workshop
21-27 Sept	Melkassa and Addis Ababa, Ethiopia	PVS training workshop
29 Sept -3 Oct	Addis Ababa, Ethiopia	TL II first annual review and planning workshop
4 -5 Oct	Awassa, Ethiopia	Field visit to Southern Agricultural Research Institute bean program in Awassa.
6-9 Oct	Bukavu, DR Congo	HarvestPlus DR Congo planning workshop
9-11 Oct	Butare, Rwanda	HarvestPlus Rwanda planning workshop,
11-13 Oct	Arusha, Tanzania	TL II Tanzania planning meeting and field visits at Selian Agricultural Research Institute
21-24 Oct	Lilongwe, Malawi	SABRN/ECABREN Joint Planning and review workshop
7-11 Nov	Nairobi, Kenya	Second national workshop and exhibition on the strategy for revitalizing agriculture (SRA) and Vision 2030
14-22 Nov	Yaounde, Bafossum and Muea, Cameroon	Field visits to IRAD/ WECABREN bean research trial sites in Bafossum and Ekona regions, Cameroon
11-14 Dec	Wageningen University, Netherlands	Ethical issues in Biofortification workshop,

The Monitoring and Evaluation Specialist:

Date	Destination	Event or purpose
8-10 Jan	Kampala	Uganda-PABRA Quarterly Planning meeting
20-26 Jan	Kampala	Uganda- PABRA stakeholders workshop
16-20 March	Lusaka,	PABRA Steering Commitee Meeting
5-11 April	Cali Colombia	CIAT Annual Meeting
7-9 Oct	Rome	F2F knowledge sharing workshop
23-25 Oct	Lilongwe	Joint PABRA Network meeting

The Agricultural Economist:

Date	Destination	Event or purpose
22-27 Sept.	Nazareth, Ethiopia	workshop on participatory variety selection
29 Sept-3 Oct.	Addis Ababa	TL2 annual review and planning meeting
9-10 Feb.	Malawi	TL2 breeders meeting

Activity 4.2 Strengthen international collaboration through networks (Intra- and inter-network collaboration), bi-lateral relations, and/or joint special projects

Highlights:

- The Pan African Bean Research Alliance (PABRA) continued to provide funding support to research for development sub-projects within the SABRN

4.2.1 Projects developed in Africa

4.2.1.1 List of ongoing special projects

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
TL1: Improving tropical legume productivity for marginal environments in sub-Saharan Africa (African component)	BGMF	2007-2010	115,000		115,000
TL2: Enhancing grain legumes' productivity, production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia: Seed Systems (African component)	BGMF	2007-2010	2,866.084 1, 368,000 million seed systems	601,250	502,866
Getting back to basics: creating impact-oriented bean seed delivery systems for the poor in Malawi, Mozambique and Tanzania	McKnight Foundation	2007-2010	US$ 400,000	300,000	100,000
Improved Smallholder food Security, Nutrition and Income through Increased Production and Marketing of Climbing Beans.	McKnight Foundation	2007-2010	US$ 400,000	300,000	100,000
Fighting Drought and Aluminium Toxicity: Integrating Genomics, Phenotypic Screening and Participatory Research with Women and Small-Scale Farmers to Development Stress-Resistant Common Bean and Brachiaria for the Tropics	BMZ	2006-2009			US 63,185
Increasing Food Security and Rural Incomes in Eastern, Central and Southern Africa through Genetic Improvement of Bush and Climbing Beans (African component)	RF	2005-2008	US 254,000	-	76,739

Supporting improved nutrition, food security and community empowerment for poverty alleviation – PABRA	SDC	2007-2008	US 944,616	944,616
Supporting improved nutrition, food security and community empowerment for poverty alleviation – PABRA III	CIDA	2003-2008	US5,298.787	2,231,057

4.2.1.2 Regional research subprojects under SABRN

The bean research for development activities within SABRN are largely financed through PABRA, with funding from CIDA-Canada, and SDC-Switzerland. Within PABRA there is strong emphasis on international collaboration through networking both within (SABRN) and between networks (SABRN and ECABREN). Additional activities are funded through special projects - like the McKnight Foundation supported: bean seed systems and climbing bean projects. Through network collaboration different countries implemented research for development activities that contributed to the outputs and outcomes in the PABRA log frame in 2008.

Activity	Value	Country
1.1.1 Complete germplasm collection, characterization and mineral analysis for all accessions	1000	DRC
	3000	Zambia
1.1.2 Conduct multi-location evaluations and national performance trials	650	Angola
	500	DRC
	1500	Malawi
	600	Mozambique
	800	Swaziland
	1500	Zambia
	1000	Zimbabwe
1.1.3 Analyze candidate varieties for minerals and protein in some countries in SABRN	1000	Angola
	1000	Malawi
	400	Mozambique
1.1.4 Develop descriptors for candidate varieties	500	Malawi
	300	Mozambique
	500	Zambia
	500	Zimbabwe
1.1.5 Conduct DUS in applicable and present for release: 3 countries in SABRN	500	DRC
	1000	Malawi
	800	Mozambique
	500	Zimbabwe

Activity	Value	Country
1.1.6 produce breeder seed in countries that have released varieties	900	Angola
	1000	Malawi
	400	Mozambique
	1000	Swaziland
	800	Zambia
	800	Zimbabwe
1.2.1 On-farm evaluations using PVS	2250	Angola
	2800	DRC
	1500	Malawi
	2600	Mozambique
	3500	South Africa
	1500	Swaziland
	3000	Zambia
	1000	Zimbabwe
1.2.2 Develop descriptors for the new bean varieties	700	Zambia
	700	Zimbabwe
1.2.3 Produce breeders' seed for the new and old bean varieties	3000	DRC
	500	Zimbabwe
1.2.4 Rejuvenate BILFA, Drought and disease nurseries	1700	Angola
	3000	DRC
	1000	Malawi
	1700	Mozambique
	1500	Zimbabwe
1.2.8 Combine resistance and select for pyramid (ALS, CBB) in ZA and BSM (MW and ZW)	1500	Malawi
	7500	Zambia
1.2.10 Selection and testing of climbing beans adapted to mid-altitude (1200 -500 masl)	1500	Angola
	850	Mozambique
	2000	Zambia
	2000	Zimbabwe
1.3.1 Identify export market potential including enhancing competitiveness of beans in SABRN	500	Malawi
	500	Zimbabwe
1.3.2 Conduct a bean cross-border trade study across South TZ, South DRC and Zambia	3000	DRC
	1500	Zambia
1.4.2 Continue with backcrossing program to improve commercial cultivars - Southern Africa	1000	Malawi
	4000	South Africa
1.4.3 Strengthen capacity for application of MAS - Bunda	4000	Malawi
1.4.6 Produce adequate seed for all breeding materials	1500	Malawi
	1500	Zambia
	1000	Zimbabwe
1.4.7 Production of foundation seed with partners	2000	DRC
	3700	Mozambique
	2000	Zambia
	1000	Zimbabwe
2.1.1 Validate effectiveness and farmers' acceptance and gender perceptions of promising ISFM and IPDM options with farmers	1850	Angola
	1000	Malawi
	500	Mozambique
	1000	Zambia
	1000	Zimbabwe

Activity	Value	Country
2.1.2 Disseminate and promote accepted options with partners for technologies in 10 all countries	1500	Malawi
	500	Mozambique
	1500	Swaziland
	2000	Zimbabwe
2.1.3 Perform cost-benefit tradeoffs analyses and adoption potential of these technologies	1000	Malawi
	1000	Zimbabwe
3.1.1 Organize, train and technically backstop community seed producers to bulk seeds	2000	DRC
	2500	Mozambique
	1000	Zimbabwe
3.1.2 Update number, type location and activities of service providers	250	Angola
	1000	DRC
	1000	Mozambique
	1000	Zimbabwe
3.2.3 Facilitate production of promotional and information publications (including publications for SABRN website), transilations in each network	950	Angola
	1000	DRC
	1000	Malawi
	1000	Mozambique
	1000	Swaziland
	1000	Zambia
	1000	Zimbabwe
5.5.2 Conduct participatory formulation and evaluation of a basket of diets for improved nutrition - using biofort products	2000	DRC
	2000	Malawi
	1500	Swaziland
	1000	Zambia
	1000	Zimbabwe
6.1.4. Conduct training workshops on nutrition assessment and linking nutrition support with agricultural extension	800	Swaziland
	1000	Zimbabwe
8.1.1 Inventory by year products (varietal and non-varietal), promotional materials	1750	Angola
	3500	Mozambique
TOTAL	**140050**	

Harvest Plus funded activities

Activity	Value	Country
1. Germplasm collection	4000	Malawi
	4000	Tanzania
	3000	Zimbabwe
2. Evaluation of fast trucks lines in various countries	2000	Angola
	2000	Lesotho
	2000	Malawi
	2000	DRC
	2000	Tanzania
	2000	Zambia
	2000	Zimbabwe

Activity	Value	Country
3. Breeding for high Fe combining with other biotic and abiotic stresses	2000	Malawi
	2000	South Africa
	2000	Tanzania
	2000	Zimbabwe
4. Supplies and small equipment: reagents, computer, printer	5000	SABRN
TOTAL	**40000**	

Contributor: R. Chirwa
Collaborators: R. Buruchara, S. Beebe

4.2.1.3 Projects submitted, Proposals and Concept notes prepared

Title	Donor	Comments	Funding period	Total amount US
Impact and development of Conservation Agriculture techniques in developing countries	European commission	Collaborators are: University of Applied Sciences Eberswalde, Germany; International Food Policy Research Institute (IFPRI), USA International, University of Ghana and Makerere University Participating CIAT technical team include: Enid Katungi and Roger Kirby	3 years	220,000 (CIAT's budget only)
Supporting Nutrition and health, Food security, Environmental Stresses and Market Challenges that contribute to improve livelihood and create income resource poor small holder families in Sub –Saharan Africa..	CIDA		2009-2013	7.8 million
Enhancing productivity, nutrition and incomes through improved marketable climbing bean and biofortified bean varieties	Government of Kenya	In review	2009-2011	$110,000
Improving Food and Nutrition Security, and Incomes of Smallholder Farmers in East and Central Africa through increased access to Markets and Technology Innovation	Belgium Development Cooperation (BADC)	Unsuccessful	2008-2011	$3,148,632

Title	Donor	Comments	Funding period	Total amount US
Climbing out from poverty: Realizing the benefits from high yield potential of Climbing beans for smallholder farmers in Africa	JICA	Presented to donor in Jan 2008		
Use of marker Assisted Selection in Developing Multiple Disease Resistant Bean Varieties in Malawi -	Kirk House Trust	Under review by donor (second round)	2009-12	150,000
(Research into Use): 'Partnership Power': Reaching women and the rural poor with new bean varieties in stress zones.	DFID	In review		£ 282,000
(Food Crisis Proposal) Addressing the Food Crisis with Sustainable Solutions: Getting High-Yielding and Adapted Bean Varieties into the Hands and Fields of Stressed African Farmers	Swiss Development Cooperation	In review		$1,920,000
Making seed security more effective in emergency, chronic stress and food crisis contexts	OFDA/USAID	In review		US 727,629

4.2.1.4 New proposals approved

Title	Donor	Funding period	Total Amount US	Amount to partners US$	Available in 2008 US$
Supporting Nutrition and health, Food security, Environmental Stresses and Market Challenges that contribute to improve livelihood and create income resource poor small holder families in Sub –Saharan Africa	SDC	2009-2011	3.2 million	2,221,384	978,616

4.2.2 Projects developed in Latin America

4.2.2.1 List of ongoing special projects at Headquarters

Title	**Donor**	**Funding period**	**Total amount**	**Amount to Partners (US $)**	**Available in 2008 (US$)**
Reducing pesticide use and pesticide resistance in rice and beans in the Andean zone	FONTAGRO	2006-2009	224.000	64.276	125.152
Fighting Drought and Aluminium Toxicity: Integrating Genomics, Phenotypic Screening and Participatory Research with Women and Small-Scale Farmers to Development Stress-Resistant Common Bean and Brachiaria for the Tropics	BMZ	2006-2009	€ 1,100,000	US153,907	US303,233
Biofortified Crops for Improved Human Nutrition – Harvest Plus Challenge Program (Yearly contracts)	Gates Foundation World Bank DANIDA, Denmark	2003-2008	305,000	50,000	255,000
Combating hidden hunger in Latin America: Biofortified crops with improved vitamin A, essential minerals and quality protein (AgroSalud)	CIDA	2004-2010	20,000,000	123,855	254,894
Integrated management of whiteflies in the tropics	DFID	2005 - 2008	259.788	7.849	22.864
Increasing Food Security and Rural Incomes in Eastern, Central and Southern Africa through Genetic Improvement of Bush and Climbing Beans (Headquarters component)	RF	2005-2008	US 254,000	-	10,750
Nutritional Improvement of the important pulse legume, the common bean, through the reduction of seed tannin content, for the benefits of people' diet in Africa and Latin America	CIDA/Univ. of Saskatchewan	2007-2010	CAD 225,000	US 32,102	US 34,503
TL1: Improving tropical legume productivity for marginal environments in sub-Saharan Africa (Headquarters component)	BMGF grant to GCP	2007-2010	1,867,328	115,000	473,944
TL2: Enhancing grain legumes productivity, production and income of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia (HQ component)	BMGF grant to CGIAR	2007-2010	3,454.802	1,104.056	197,701

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Variedades de fríjol tolerantes al estrés abiótico de la baja fertilidad y la sequía, y a la sostenibilidad productiva y alimentaria de Centroamérica	Red-SICTA, SDC	2007- 2008	246,100	-	45,450

4.2.2.2 Projects submitted, Proposals, and Concept notes prepared

Title	Donor	Comments	Funding period	Total amount US
Extracting the best from a desert species: Mining tepary bean for drought tolerance	GCP	Concept note not selected for full proposal development	2008-2011	$889,350
Basal root architecture and drought tolerance in common bean	GCP	Concept note and full proposal approved	2008-2011	$ 345,000
Integrated experimental and modeling approach to optimize soil water use under limited water	GCP	Concept note not selected for full proposal development	2008-2011	$905,060
A cross-legume phenotyping effort to identify common traits for superior adaptation to drought	GCP	Concept note under review	2009-2011	$459,020
Improving tolerance to drought stress in crops	WUN	Seed grant under review	2009	$48,000

4.2.2.3 New proposals approved

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Biofortificación del Frijol Común (*Phaseolus vulgaris* L.) en Panamá con Micronutrientes"	SENACYT – Panama	2008-2011	12,000		7,000
Improved beans for Africa and Latin America	DFID, UK	2008	120,690	-	120,690
Characterization of bean diversity in Central Europe	GCP	2008-2009	9,000	-	9,000

Title	Donor	Funding period	Total amount	Amount to Partners (US $)	Available in 2008 (US$)
Dry bean improvement and marker assisted selection for diseases and abiotic stresses in Central America and the Caribbean"	GCP	2008-2009	40,120	-	40,120
Capacity Building Needs regarding the Tropical Legume I (TLI) Project	BMGF grant to GCP	2008-2009		5,904	5,904
Obtención y evaluación de *Phaseolus vulgaris* y *Zea mays* tolerantes a la sequía	CYTED, Spain	2008-2009	$1,000,000	-	29,906
Development of a management system of *Bemisia tabaci* in paprika and pepper in the Cauca Valley Gracias	MADR	2008-2011	58,288		16.560
Improvement of Chitti bean in Iran. SPII, Iran	Iranian government	2008	18,423	-	18,423

Activity 4.3 Supporting breeding programs in NARS, regional networks, farmers' associations, and CIALs with germplasm and technical knowledge

Highlights:

- More fixed lines with high yield potential and resistance to diseases and cultivars of commercial value for export market were distributed in a regional yield trial to various NARIs partners in different countries.
- Early generation selections of interspecific crosses for high iron have been realized in ICTA, Guatemala and are pending shipment to CIAT for analysis.
- Selections from EAP-Honduras have been analyzed and returned to the breeder there.
- High iron lines are in validation trials in Nicaragua and a variety could be released in the course of 2009.

4.3.1 Nutritional analysis of Bolivian germplasm as support for the national genebank and breeding programs

Rationale: As part of the Fontagro and Agrosalud funded projects on nutritional breeding, we have developed a strong collaboration with the Bolivian bean-breeding program and the corresponding genebank for this crop. Bolivia is a primary center of diversity for Andean genepool germplasm within the Andean region of South America. The country has the most significant problems of malnutrition on the continent (51% anemia in children under 5 year old and 33.1% in women 15 to 49 years old) and there is a need for higher micronutrients in the diet of most consumers. Common bean, especially biofortified varieties, could provide significant levels of iron and zinc to diets of consumers who eat 10 Kg or more per person per year. Common bean, however, is a relatively new grain crop for the country with most production in the eastern lowlands or sub-Andean valleys of Santa Cruz, some of it for local consumption and some for export to Colombia and other countries in the region. In this region, common bean is growing in importance compared to other pulses such as faba bean, lupines and lentils. Per capita consumption of dry beans has increased particularly among lowland producers and for people living in Santa Cruz and neighboring cities despite the fact that common bean was traditionally consumed previously as fresh green pods. The objective of this research was to screen some of the genotypes held in the national genebank collection at the "Centro de Investigacion Fito-ecogénetico" (which is part of the Pairumani Foundation) for baseline mineral content, with the aim of moving the best genotypes into the breeding program at the Universidad Autónoma Gabriel René Moreno.

Materials and Methods: A total of 183 genotypes from 19 collection sites were harvested on the Pairumani research station in Cochabamba, Bolivia in March 2008 and sent to CIAT for mineral analysis. Seed mineral content was evaluated by grinding 3 g of previously crushed, oven-dried grain (two days at 40°C) into a fine powder using a modified Retsch mill with teflon chamber and zirconium grinding balls. Powder was transferred to 30 mL plastic vials and analyzed for both iron and zinc concentration measured in parts per million (ppm) with Atomic Absorption (AAS) spectrophotometry in the Analytical Services laboratory of CIAT. Data was analyzed with the software package Statistix v. 8.0 to determine descriptive statistics and correlation values between minerals.

Results and Discussion: Average seed iron and zinc content for the genotypes from Bolivia were 56 ppm and 26 ppm, respectively. The range in iron concentration 34 to 88 ppm, while for zinc the concentrations ranges from 18 to 38 ppm (Table 113, Figure 60). The lines with highest iron are shown in Table 114 and included 19 genotypes with over 65 ppm iron. Zinc concentration was acceptably high in some of the genotypes from this group (for example A48 with 34 ppm, K17 with 35 ppm, J11 with 35 ppm and F23 with 38 ppm (Table 114). Correlation between iron and zinc concentrations were highly significant (r=0.52, P<0.0001).

Table 113. Descriptive statistics for iron and zinc content in a 183 genotypes from the germplasm collection of Bolivia.

	Fe ppm	**Zn ppm**
N	183	183
Mean	56	26
SD	8.11	3.56
Variance	65.77	12.66
SE Mean	0.60	0.26
C.V.	14.49	13.45
Minimum	34	18
Median	56	27
Maximum	88	38
Skew	0.62	0.26
Kurtosis	1.41	-0.04

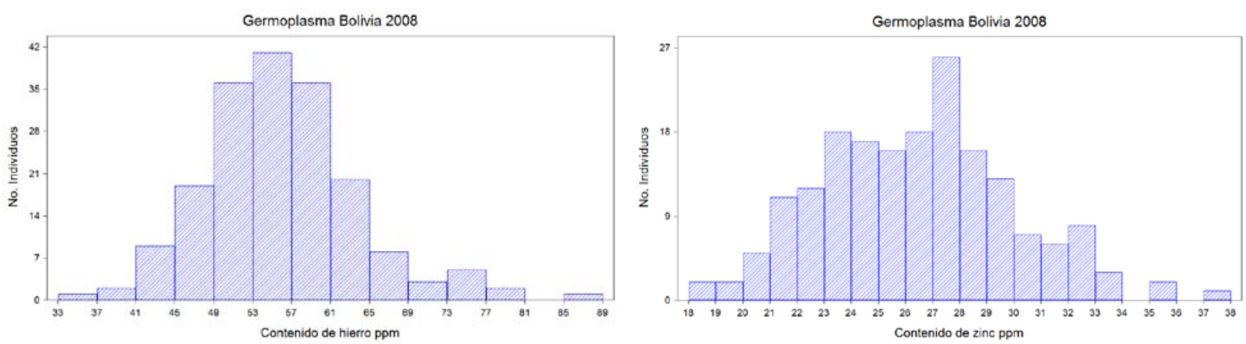


Figure 60. Population distribution for iron and zinc content among 183 genotypes from the germplasm collection of Bolivia.

Table 114. Best iron levels found in each of 19 collections of genotypes from the germplasm bank of Bolivia.

Germplasm collection	Fe ppm	Zn ppm
G8	88	33
A19	80	31
G7	78	33
A11	77	30
A48	75	34
G1	75	33
A16	75	28
F23	74	38
J11	72	35
J23	71	33
B28	70	31
K2(B)	68	24
A44	68	27
A49	67	30
J9	66	30
B15	66	28
J14	66	30
J49	66	30
J55	65	22

Conclusions and Future Plans: In general the results reflected the higher iron status, but lower zinc status of Andean grain types. While some high iron genotypes were found none were as high as for values seen for improved breeding lines from the biofortification program. Therefore the Bolivian genotypes should be considered as intermediate sources of high-mineral traits that can be used in breeding programs with improved varieties such as the NUA lines.

Collaborators: M.W. Blair, C. Astudillo (SBA-1, CIAT), T. Avila, G. Avila, R. Rios (Fund. Pairumani, Cochabamba); J. Ortubé, T. Anzoátegui, J. Padilla (UAGRM, Santa Cruz)

4.3.2 Selection by NARS of segregating populations for nutritional quality

4.3.2.1 Progress in selection of cycle 2 populations in Central America

In 2007 elite populations combining high mineral parents with sources of agronomic traits were distributed to collaborating partners in El Salvador, Guatemala, Honduras, and Nicaragua. These populations were created simultaneously with those reported under product 1. These have been selected for local adaptation and for resistance to diseases, especially BGYMV, and have reached the F_5 generation in most cases. In Nicaragua the populations have been managed as bulks to date and advanced lines are not yet available for mineral evaluation. Grain is being shipped to Colombia for mineral analysis on the selected families made in El Salvador and Guatemala (Table 115). In the case of the populations selected in a highland environment in Guatemala, it is noteworthy the number of families that are derived from *P. polyanthus* (G35575) and *P. coccineus* (G35999). These species are native to this region, they tend to express resistance to most diseases that are endemic to highland areas, and it was hoped that the populations would perform relatively better here. As reported above under Product 1, in Colombia G35575 has given the highest level of iron among all parents used in crosses. Therefore it will be especially interesting to see what levels of iron are obtained from these selections.

Table 115. Populations segregating for mineral content, created in CIAT and selected locally by national program breeders in Central America.

Country	Population	Number of selections
El Salvador	(SER 155 x RCB 234) x (MIB 451 x MIB 487)	37
Guatemala	SBCF 16170	2
	SBCF 16175	2
	SBCF 16176	8
	SDFZ 16180	1
	SDFZ 16181	3
	SDFZ 16191	10
	SDFZ 16200	2
	SBCF 16173	4
	(SXB 414 x (ICTA Hunapu x G 35575-2P)	2
	(ICTA Hunapu x (ICTA Hunapu x G 35575-2P)	1
	(SXB 414 X (ICTA Altense x G 35999-8P)	3
	(ICTA Altense X (ICTA Altense x G 35999-8P)	2
	Hunapu x (G 23823E x ASC 81)	5
	Altense x (G 23818B x ASC 82)	3
	(ASC 86 x (G 23823E x G 35575-2P)	2
	(ASC 89 x (G 23823E x G 35575-2P)	2
	(ASC 91 x (G 23823E x G 35575-2P)	1
	(ASC 92 x (G 23823E x G 35575-2P)	2
	(ASC 88 x (G 23818B x G 35575-5P)	1
	(ASC 91 x (G 23818B x G 35575-5P)	2
	(ASC 92 x (G 23818B x G 35575-5P)	2
	(ASC 84 x (G 23818B x G 35575-5P)	5
	(ASC 87 x (G 23834E x G 35999-8P)	2
	(ASC 91 x (G 23834E x G 35999-8P)	3
	(G 23834E x G 35999-8P) x ASC 91	6
	(ASC 85 x (G 23834E x G 35999-8P)	4

In the Panamerican School at Zamorano, 26 populations to produce red and black seeded cultivars were created on site in 2005 employing parental sources for high iron from CIAT. Selection on these continued during 2007 and 2008 (Table 116). More than 350 lines have been developed (Table 117). Parental materials that were combined with the high iron parents included sources for abiotic stress (drought and low fertility), and important diseases (BGYMV, angular leaf spot and web blight in particular). Samples of 28 advanced lines from the BIOFOR and FEZ populations were sent to CIAT and have been analyzed for minerals, as well as lines in regional trials. Interpretation of the data is pending.

Table 116. Chronology of the development and selection of populations and lines for high levels of minerals combined with agronomic characteristics. Zamorano, 2006-08.

Population	No.	Planting season [z]				
		06B	07X	07A/B	08A	08B
FEZ 0521-0532	12	712 F_3	293 F_4	52 F_5	97 F_6	47 F_7
FES 0551-0554	4	215 F_3	73 F_4	15 F_5	27 F_6	16 F_7
BIOF 1-6	6	291 F_4	101 F_5	20 F_6	48 F_7	17 F_8
BIOF11-14	4		4000 F_2	523 F_3	248 F_4	122 F_5

[z] X= Dry season (January-April); A= First season (May-August); B= Second season (September-December).

Table 117. Numbers of lines developed from crosses between sources of high minerals and elite lines for agronomic and commercial traits. Zamorano 2008.

Pedigrees		Characters	Families
Simples:			
BIOF 1	FE14584-1/PRF9653-16B-3	Fe, Zn, MD, VA, VC	1 F_7
BIOF 2	NH21566-7/PRF9653-16B-3	Fe, Zn, MD, VA, VC	6 F_7
BIOF3	FE14584-2/EAP9503-32B	Fe, Zn, MD, VA, VC	0 F_7
BIOF 4	G23818B/EAP9503-32B	Fe, Zn, MD, VA, VC	12 F_7
BIOF 5	G23823E/EAP9712-13	Fe, Zn, MD, VA, VC	18 F_7
BIOF 6	G23834E/ALS9952-27R	Fe, Zn, MD, VA, VC	11 F_7
Triples:			
FEZ 0521	Amadeus 77//BIOF 1	Fe, Zn, MD, VA, VC	5 F_6
FEZ 0522	Cardenal//BIOF 3	Fe, Zn, MD, VA, VC	12 F_6
FEZ 0523	DEOHRO//BIOF 4	Fe, Zn, MD, VA, VC	9 F_6
FEZ 0524	SRS 6-6//BIOF 1	Fe, Zn, MD, VA, VC, SQ	4 F_6
FEZ 0525	MR14292-2//BIOF 3	Fe, Zn, MD, VA,VC, SQ	8 F_6
FEZ 0526	MH 2-2//BIOF 1	Fe, Zn, MD, VA, VC, MH	3 F_6
FEZ 0527	ALS9952-27R//BIOF 5	Fe, Zn, MD, VA, VC	4 F_6
FEZ 0528	MH 43-3//BIOF 1	Fe, Zn, MD, VA, VC, MH	10 F_6
FEZ 0529	PRF9924-50N//BIOF 5	Fe, Zn, MD, VA, VC	12 F_6
FEZ 0530	BCN20-02-94//BIOF 3	Fe, Zn, MD, VA, VC	16 F_6
FEZ 0531	Amadeus 77//BIOF 2	Fe, Zn, MD, VA, VC	10 F_6
FEZ 0532	Cardenal//BIOF 6	Fe, Zn, MD, VA, VC	4 F_6

Pedigrees		Characters	Families
Doubles:			
FES 0551	SRS2-4//BIOF 1	Fe, Zn, MD, VA, VC, SQ	3 F_6
FES 0552	SRS2-5//BIOF 3	Fe, Zn, MD, VA, VC, SQ	7 F_6
FES 0553	SRS2-18//BIOF 1	Fe, Zn, MD, VA, VC, SQ	6 F_6
FES 0554	SRS2-20//BIOF 3	Fe, Zn, MD, VA, VC, SQ	11 F_6
BIOF 11	FEZ 0521//ALS 0531	Fe, Zn, MD, VA, VC, MA	44 F_4
BIOF 12	FEZ 0522//ALS 0532	Fe, Zn, MD, VA, VC, MA	34 F_4
BIOF 13	FEZ 0528//ALS 0545	Fe, Zn, MD, VA, VC, MA	75 F_4
BIOF 14	FEZ 0529//ALS 0546	Fe, Zn, MD, VA, VC, MA	95 F_4

4.3.2.2 Selection of populations in Brazil

The bean program of EMBRAPA in the CNPAF station in Goiania, Goias has continued to pursue the development of drought tolerant lines with high mineral content, and has a very effective selection site for drought evaluation in Porangatu. Selection has progressed within populations and families for drought and minerals, both those created in house and those sent from CIAT-Colombia. Numbers and type of selections are summarized below:

- 28 $F_{3.5}$ families from CNPAF populations among 16 elite parents
- 113 $F_{1.4}$ families from 19 populations from CIAT and 6 from CNPAF
- 48 $F_{1.5}$ families from 19 CIAT populations
- 90 $F_{8.9}$ lines from 35 lines sent from CIAT
- 13 advanced lines sent from CIAT
- 3 interspecific populations from CIAT for drought tolerance
- 68 F_4 families from CIAT for high minerals

The EMBRAPA laboratory for mineral analysis has also reported atomic absorption data on two universal checks sent from CIAT that approach the values with ICP quite satisfactorily (61 with atomic absorption versus 65 with ICP for low iron; 94 versus 102 for high iron).

4.3.3 Evaluation of lines from the 1st cycle of selection in advanced yield trials and validation in Central America

Although plans were made during the annual meeting of the PCCMCA in April, 2008 to execute a broad evaluation of advanced lines as selected in previous years, very few trials were salvaged given the very excessive rainfall throughout the growing seasons. Nearly all trials were lost in El Salvador.

4.3.3.1 Nicaragua

Nicaragua is the country where the testing of advanced lines in regional trials has advanced the most. In a regional trial the selections from populations for high iron were compared with local check INTA Rojo (Table 118). Across all five environments only two lines compared favorably with INTA Rojo. But in the less favorable environments (Boaca and Las Segovias) with yields that are more typical of those obtained by farmers, more lines yielded comparably or with a modest advantage. However, the widest advantage in relation to INTA Rojo was in the trial in San Isidro, a high yield environment. In Nicaragua it is common for genotypes to present local or regional adaptation, and the varietal release procedure there permits the registration of cultivars for regional use. Grain has been recovered from these trials, and is awaiting chemical analysis in CIAT.

Table 118. Yield of lines (kg ha^{-1}) selected from populations with high iron parents in five regions of Nicaragua.

	Carazo (La Compania)	Carazo (Aguacate)	Boaca (Sta Lucia)	Las Segovias	Sn Isidro	Mean
194-15488-30	2171	2110	1646	1274	2426	1925
199-15488-32		2192	1528	1090	2626	1859
INTA Rojo (check)	2224	2653	1308	1174	1928	1857
181-15488-52	2072	2329	1360	1128	2311	1840
196-15488-30	2142	2355	1278	1054	2150	1796
126-15357-30	1971	2355	1676	962	1887	1770
15357-30	2131	1883	1390	1404	2001	1762
189-15488-30	2119	1976	1386	1178	2152	1762
187-15488-39	1872	2314	1534	1154	1897	1754
MIB 397	1768	1693	1368	1156	2618	1721
428-15094-39-4	2060	2113	1422	1224	1576	1679
202-15488-39	1635	1842	1480	1046	2359	1672
MIB 438	2193	2125	1178	1296	1541	1667
519-15089-22-55		1909	1386	1184	2134	1653
190-15488-30	1687	1693	1240	1320	2108	1610
MIB 396	1579	2097	1056	1038	1970	1548
197-15488-30	2088	1762	1332	834	1428	1489
MIB 395	1728	1732	850	936	1478	1345

In the region of Las Segovias two selections from the AgroSalud project are being evaluated in validation plots on farm (approximately 100 m^2 per line). DFSZ 15094-43-5 has been tentatively named INTA Nutritivo, and DFSZ 15094-39-4 has been designated INTA Ferroso. The latter line has performed better in these trials. These names do not imply that these materials have been released, but rather they have been applied to make the lines "user-friendly" in collaboration with farmers. INTA has the intention of releasing a variety in the course of 2009.

4.3.3.2 Honduras

In Honduras 20 trials of the 4 most promising lines were distributed to DICTA, FAO, Rural Reconstruction, and FIPAH (an NGO working with farmer research committees). Data are still pending at the time of writing. Grain was recovered from 4 trials for chemical analysis in CIAT (results pending). The yield trial reported from Zamorano station was planted in very favorable conditions (Table 119), and even here, variability in the field was great. Selected lines did not yield as much as elite cultivar Amadeus, but presented a wide margin over local cultivar "Rojo de Seda".

Table 119. Yield, agronomic and commercial value of lines and checks in the regional high mineral nursery. Zamorano 2008.

Line	Yield (kg ha^{-1})	Agronomic value (1-9)	Commercial value (1-9)
Amadeus 77	4,940	3.6	4.0
703-SM 15216-11-4	4,019	5.3	3.0
523-DFBS 15092-04-4	3,646	4.7	4.0
519-DFBS 15089-22-5	3,358	3.3	3.5
428- DFSZ 15094-39-4	3,320	4.7	4.0
Seda	2,474	8.0	2.0
LSD 0.05	1,312	0.7	1.0

The 4 lines were subjected to a systematic evaluation of acceptability traits (grain color, textura and viscosity) in Food Science Laboratory of Zamorano (Table 120). Color was determined by the Colorflex Hunter L*a*b. Texture was estimated by the Instron Series IX version 8.12.00. Grain is considered cooked if it requires less than 500 Newtons to be compressed in the texturometer. By this criterion, the 4 lines showed an optimal cooking time of 60 minutes. Minimum broth viscosity should be 13.2 cP at 60 minutes of cooking; by this criterion the lines 523- DFBS 15092-04-4, 429-DFSZ 15094-39-4 and the check Seda produce the best broth.

Table 120. Results of the analysis of color, texture, and broth viscosity on four lines and two checks. Zamorano, 2008.

Line	Color (1-9)	Texture (N)	Viscosity (cP)
703-SM 15216-11-4	1	300.67	11.43
523-DFBS 15092-04-4	1	335.33	14.17
519-DFBS 15089-22-5	1	316.67	12.33
428- DFSZ 15094-39-4	1	345.67	13.33
Amadeus 77	2	298.67	12.70
Seda	1	249.33	13.67

4.3.3.3 Brazil

Evaluations in Brazil of materials sent from CIAT are normally 1-2 years behind those in other countries, due to the need to pass seed through laboratory and greenhouse quarantine, and then to increase seed coming out of the greenhouse. In 2008 it was possible to report data on the High Mineral Nursery, and to correlate data with those from Central America.

Collaborators: Juan Carlos Rosas (EAP), Julio César Villatoro (ICTA), Julio Molina (INTA), Aurelio Llano (INTA), Maria José Peloso (EMBRAPA), S. Beebe, R. Urbina

4.3.4 Evaluation of SU91 as a molecular marker for CBB resistance in common bean for Southern Africa

Rationale: Common bacterial blight (CBB) is an important foliar and seed-borne disease of Andean beans grown in tropical lowland and mid-elevation areas of Africa, Central America and the Caribbean. The disease is also important in the subtropic and temperate regions of the Americas and Africa during hot, humid summer weather. The disease is caused by the pathogen *Xanthomonas axonopodis* pv. *phaseoli* (Xap), which is widespread and part of a complex of Xanthomonad bacterial pathogens attacking many broadleaf and vegetable crops. Races of the Xap pathogen are not recognized. The current level of CBB resistance in Andean genotypes is insufficient and most current Andean varieties are highly susceptible especially in Southern Africa. With this in mind we have implemented marker assisted selection for the major QTL for common bacterial blight resistance tagged by a SCAR marker developed at CIAT called SU91 as part of the breeding program and within an M.Sc. program for SABREN/Univ. of Zambia. As sources, we are using mainly VAX and XAN lines developed in the 1990s, but also are testing RMX lines developed by us in 2004 from crosses of Caribbean type red mottled beans with the sources VAX3 and VAX6.

Materials and Methods:

<u>Genotypes:</u> A total of 28 genotypes were used in initial testing of the SU91 marker. The control genotypes were the resistance sources RMX2, RMX19, RMX20 (Andean) and VAX3, VAX6 and XAN159 (Mesoamerican), while the other genotypes were the red, cream mottled or red mottled advanced lines CAL143, CMB106, DRK149, RAA21, RMA68, RMA70, RMA71 and RMC57. In addition the drought adapted genotypes SAB575, SAB581, SEQ11, SEQ1003, SEQ1004, SEQ1006 and SEQ1027 were tested as well as the BCMNV sources used in crosses with these previous parents BRB264, BRB265, BRB266 and BRB267.

<u>DNA extractions:</u> Two types of DNA extraction were used, namely alkaline extraction (microprep) and proteinase K (miniprep) derived DNA. Once these parental genotypes were evaluated the SU91 marker was tested on a set of gamete selection F_1 plants from semester 2008b derived from simple, double and multiple crosses between the parents and using alkaline extraction. Initial marker assisted selection targeted those crosses with VAX3 and VAX6 where the SU91 marker seemed to be more reliable.

Results and Discussion: SU91 was found to amplify multiple background bands with alkaline extraction DNA as template compared to miniprep DNA as template when using 2.5 mM MgCl2 (Figure 61). The strongest band was found for the genotypes VAX3, VAX6 and XAN159 at the expected size of 700 bp, but the SU91 marker was also found to be sensitive to template DNA concentration with a weak band of the expected size appearing when concentrations were high in susceptible genotypes, especially with alkaline extraction DNA.

Given these initial results, we tried two different dilutions of miniprep and alkaline extraction DNA for VAX3, VAX6 as resistant controls and MAR1 as a susceptible control. The results showed that a dilution of 1:9 produced a strong band in the resistant genotypes and no band in the susceptible genotypes; while a dilution of 1:14 produced a weak band only for VAX6 not for VAX3 or the susceptible check (Figure 62). We then attempted marker assisted selection using alkaline extraction DNAs from a set of 331 gamete selection from the Palmira 2008B season that were used for leaf tissue harvesting 18 days after planting. Amplification of the template DNA was based on a 1:9 dilution and the same PCR conditions as used for the control genotypes. Since the marker is dominant and in *cis* orientation with the resistance QTL only those plants containing the 700 bp SU91 band and no other background bands were selected. Given this stringent evaluation, a much lower number of positive genotypes (2.1%) were identified than expected based on the pedigrees of the triple, double or multiple crosses evaluated.

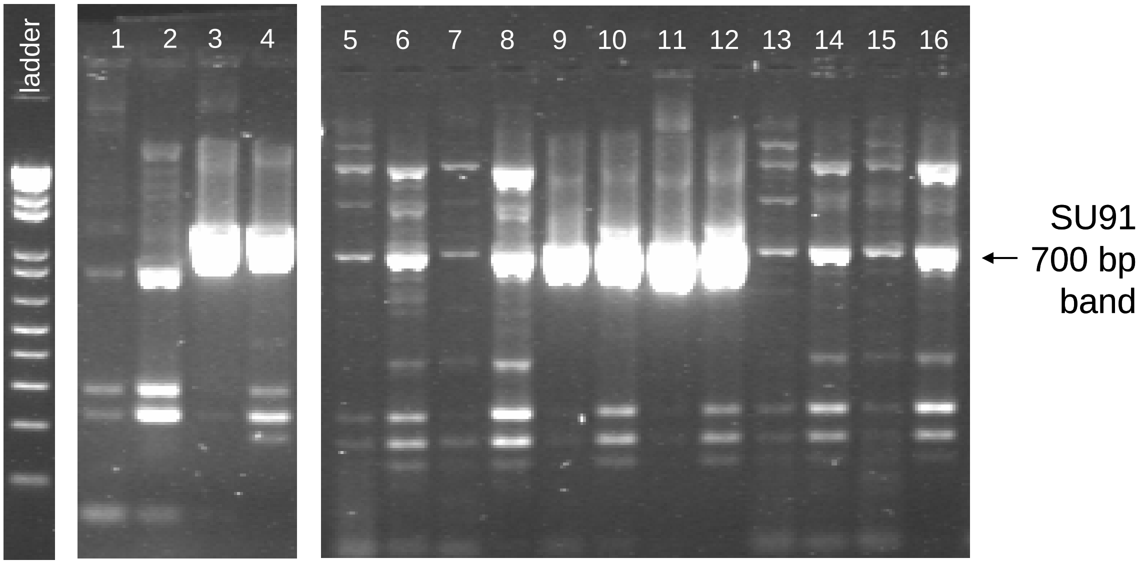


Figure 61. Sample of SU91 testing on drought tolerance and CBB resistance control genotypes: MAR1 (lanes 1 and 2); XAN159 (3 and 4), SEQ1004 (5 and 6), SAB568 (7 and 8), VAX3 (9 and 10), VAX6 (11 and 12), SAB514 (13 and 14), SEQ1027 (15 and 16). All odd-numbered lanes are the results of PCR amplifications from miniprep DNA while all even-numbered lanes are from alkaline extraction DNA (1:4 dilutions).

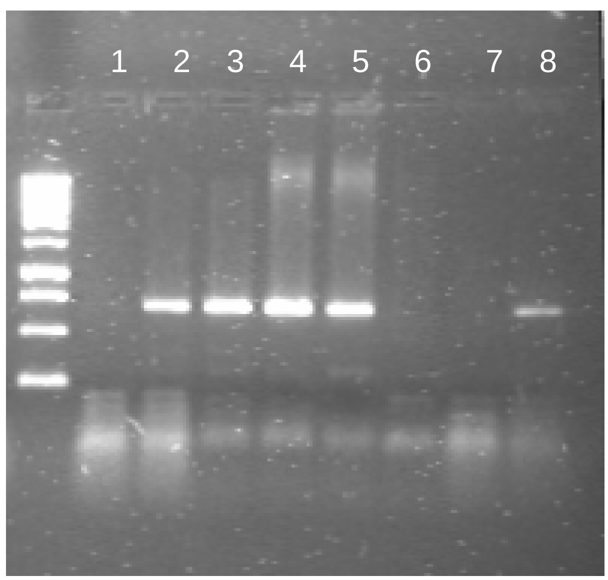


Figure 62. Dilution tests for the SU19 markers: dilution of 1:9 tested on alkaline extraction DNA of MAR1 (lane 1), VAX3 (lane 2), and VAX6 (lane 3), and on miniprep DNA of the latter VAX genotypes (lanes 4 and 5, respectively); followed by dilution of 1:14 tested on alkaline extraction of MAR1 (lane 7), VAX3 (lane 7), and VAX6 (lane 8).

Conclusions and Future Plans

Initial testing of the SU91 marker shows that it is a difficult marker to use on the widely divergent DNA types we routinely analyze for other markers, therefore further trouble shooting will be necessary, or a new marker will need to be identified. The difficulty in using this marker may derive from the fact that the VAX lines as well as some of the XAN lines (such as XAN159 and XAN309) which are the sources of SU91 tagged resistance were produced by inter-specific hybridization between common bean (*Phaseolus vulgaris* L.) and tepary bean (*P. acutifolius* Gray) and evaluated in Mesoamerican genepool material, therefore the PCR amplification product may be difficult to detect in some genetic backgrounds especially from the Andean genepool.

Collaborators: M.W. Blair, H.F. Buendia (SBA-1, CIAT) L. Kalalokesya (Univ. of Zambia), R. Chirwa (CIAT-Malawi)

4.3.5 Distribution of seed from CIAT Headquarters

Tables 121, 122 and 123 show a summary of Bean Breeding, Andean Breeding and other nurseries distributed from CIAT headquarters to partners and collaborators.

Table 121. Nurseries distributed by the Mesoamerican bean breeding section.

Description	No. of lines	Purpose	Institution/ Collaborators	Country
Black and red lines tolerant to drought	65	Local Evaluation	Ministry of Agricultura Roberth Shank	Belice
Bean lines tolerant to low fertility	2	Local Evaluation	Root Biology Center, South China Agricultural Univ. Xialong Yan	China
Black and red lines, high minerals	8	Local Evaluation	Corpoica Cesar Adriana Tofiño	Colombia
Black line, high minerals	1	Local Evaluation		
Black lines tolerant to drought	18	Local Evaluation		
Bean lines tolerant to drought and high minerals	7	Local Evaluation		
Black line	1	Local Evaluation	Semillas Camerún Gilberto Bastidas	Colombia
MIB 488	1	Local Evaluation	UMATA, Palmira Sandra Salazar	Colombia
Andean bean lines tolerant to drought	123	Local Evaluation	INIAP Esteban Falconi	Ecuador
Bean lines tolerant to drought and low fertility	24	Local Evaluation	National Research Centre Botany Department Magdi Abdelhamid	Egypt

Table 121. cont´d.

Description	No. of lines	Purpose	Institution/ Collaborators	Country
$F_{4.5}$ RILs, Mesoamerican and Andean bean lines tolerant to drought, low fertility; and *bc*-3, ALS and Anthracnose differentials; Zabrotes sources	312	Local Evaluation	Melkassa Agricultural Research Center Teshale Assefa	Ethiopia
RILs, MesoAmerican and Andean bean lines tolerant to drought, low fertility, bc-3, ascochyta, and CBB, ALS and anthracnose differentials	192	Local Evaluation	Awassa Agricultural Research Center Asrat Asfaw Amele	Ethiopia
Bean lines tolerant to drought, Fe, low fertility and *bc*-3	85	Local Evaluation	ORE Eliassaint Magloire	Haiti
F_2 populations drought	8	Local Evaluation	University of Nairobi Paul Kimani	Kenya
RILs of BAT 881x G21212 and G 40159	101			
F_2 populations drought	15	Local Evaluation	Chitedze Agric. Res. Stat. Rowland Chirwa	Malawi
Andean bean lines tolerant to drought	114			
RILs of DOR 364 x BAT 477	100			
Black, white and red bean lines tolerant to drought	21	Local Evaluation	INIFAP Fermín Martinez, Alfredo Vargas	Mexico
Black and red bean lines tolerant to drought, with *bc*-3	108	Local Evaluation	INIFAP Jorge Acosta	Mexico
VAM (High minerals nursery)	43	Yield evaluation and Nutritional studies	IDIAP Emigdio Rodríguez	Panama
RILs of DOR 364 x BAT 477	100	Local Evaluation	Mayagüez University Timoty Porch	Puerto Rico
Bean lines tolerant to aluminum, drought, low fertility; or with bc-3, anthracnose, rust and ALS differentials	394	Local Evaluation	ISAR Felicite Nsanzabera	Rwanda
High mineral bean lines	15	Local Evaluation	Institute of Food Science and Nutrition Nicolai Petry, Monika Egli	Sweden
ALS bean lines	2	Research	USDA-ARS Marcial Pastor-Corrales	USA

Table 122. Nurseries distributed by the Andean bean breeding and Germplasm Characterization section.

Description	No. of seeds	No. of lines	Purpose	Institution/ Collaborator	Country
BAT 93 , G19833	1 kg	2	Mutagenesis	Agriculture and Biotechnology Lab. IAEA/Rownak Afza-Chikelu Mba	Austria
RIL s of G2333 x G19839 Accessions and bean lines G2333 and G19839	100 100 1 kg	76 19 2	BNF Evaluation	Centre of Microbial And Plant Genetics/ Jos Vanderleyden, Lara Ramaekers	Belgium
Bush bean lines Climbing bean lines	1 kg 500 g	6 4	Nutritional quality Agronomic testing	CORPOICA-Rionegro/ Alejandro Navas	Colombia
Accessions and bean lines	250 g	30	Agronomic testing	CORPOICA-Valledupar/ Adriana Tofiño	
Bush and climbing bean lines	250 g	9	Adaptation	FIDAR/ José Restrepo	
Bean accessions	30	9	Disease screening	Univ. Nacional de Colombia Luz Nayibe Garzón, Gustavo Ligarreto	
Climbing bean lines	250 g	12	Adaptation testing at low altitude	Institut National Pour L Etude Et La Recherche/ Jean Paul Lodi Lama, Bernard Vanlauwe Agonomique	DRC
4 lines (5 accessions) *Acutifolius*, *coccineus*, and *lunatus* accessions	120 g 20	9 8	Nutritional evaluation	Univ. of Aarhus, Cristina Cvitanich	Denmark
RILs of DOR364 x BAT477 Anthracnose differentials ALS differentials	100 30 30	100 12 12	Drought evaluation Crossing block	Awassa Agricultural Research Center/ Asrat Asfaw Amele	Ethiopia
Bush and climbing bean accessions (reference collection)	30	124	Adaptation trials		
Kenya and Ethiopia accessions	100	204	Adaptation trials		
DOR390 x (DOR390 x (G 24423 x DOR390)) lines	40	138	Adaptation trials		
Accessions (reference collection), 3 reps. 2 trials	40	234	Adaptation trials		

Table 122. cont´d.

Description	No. of seeds	No. of lines	Purpose	Institution/ Collaborator	Country
RMA lines	40	73	Adaptation trials	Melkassa Agricultural Research Center/ Teshale Assefa	
MBC lines	40	138			
F_2 Individual Selections Crosses for Zabrotes with Awash Melka	30	332	Field selection Based on MAS evaluation		
F_2 and F_3 populations of crosses for CBB	350	36	Field selection Thesis trials	CIAT-SABRN/ Rowland Chirwa	Malawi
Bush and climbing bean accessions (reference collection)	30	219	Root architecture screening	IIAM/ Magalhaes Miguel, Celestina Nhagupana Jochua	Mozambique
G19833 x BRB lines	30	181			
RIL s of G2333 x G19839	30	86			
NUA lines	50	50	Adaptation trials	IDIAP/Emigdio Rodríguez	Panama
NUA lines, 2 reps. 4 trials	40	64	Nutritional and Quality evaluation		
NUA lines	500 g	5	Nutrition analysis	CIP/ Wolfang Gruneberg	Peru
RMA, BRB, and DRK lines, 2 reps.	40	51	Disease screening	Agricultural Research Institute Robin Buruchara	Uganda
MBC, BRB, and DRK lines, 2 reps.	40	96			
RILs of G40022 x G40186	50	79	Disease screening	University of Nebraska/ James R Steadman	USA
RILs of G40186 x G40022	50	83			
RAD-CERINZA x (RAD-CERINZA x (G10022 x RAD-CERINZA))	50	145			
P. acutifolius accessions	30	42	Genetic analysis	Virginia State University/ Harbans L Bhardwaj	
Andean and Mesoamericans accessions	20	20	Thesis evaluation	INIA-CENIAP/ Miguel Alexis Adrian Perez	Venezuela
RMC bgm-1 + lines	30	26			
DOR 390 x (DOR 390 x (G 24423 x DOR 390))	20	100			

Table 123. Other nurseries distributed

Description	No. of lines	Purpose	Institution/ Collaborator	Country
Macrophomina and *fusarium oxisporum* Isolates	1	Academic studies	Carlos Huertas, Univ. Nacional de Palmira	Colombia

4.3.6 Distribution of germplasm within the ECABREN bean network

Description	No. of nurseries sent	No. of entries	Purpose	Recipients	Country
Bioforts and Bilfa V lines	2	31	Adaptation and selection trials	Mr. Gabriel Diasso	Burkina Fasso
Pythium Root rot	1	22	Research	L. Nounamo	Cameroon
Root rot Nursery of 68	1	7	Research	L. Nounamo	Cameroon
Pythium Root rot BC- S5 progenies	1	12	Research	L. Nounamo	Cameroon
Root Rot resistant lines, Advanced small, medium and large white lines (16 April 2008)	1	17	Adaptation trials in WECABREN	Lodi Lama, INERA-Mvuasi,	DRC
TL II materials	25	346	Drought phenotyping and selection	Dr Setegn Gebeyehu	Ethiopia
Pythium Root rot RILs	1	24	Research	R. Otsyula	Kenya
F_8 lines having both ALS and Pythium root rot resistance	1	3	Research	R. Otsyula	Kenya
BCS_5 F_5 (GLP 2 x RWR 719) progenies	1	9	Research	R. Otsyula	Kenya
ALS differentials	1	12	Research	Dr Isabella Wagara	Kenya
Released bush and climbing bean varieties	1	6	On-farm testing and seed multiplication	Mr. Jarvis Njoroge	Kenya
TL II regional nursery (March 2008)	25	340	Drought phenotyping and selection trials	John Msacky, SARI	Arusha, Tanzania
TL II drought nursery	27	620	Drought phenotyping and selection trials	Dr Roland Chirwa CIAT-SABRN	Malawi
Released varieties	1	5	Seed multiplication	Dr Kiarie Njoroge Univ. of Nairobi	Kenya
RILS, Core Collections & Regional Varieties	3	201	TL 1 drought phenotying and selection trials	Festo Ngulu, SARI	Arusha, Tanzania
Anthracnose differentials	1	12	M.Sc. research	Kelvin Kamfwa, Makerere Univ.	Uganda
F_2 populations from Anthracnose program	1	12	M.Sc. research	Dr Kelvin Kamfwa Makerere Univ.	Uganda

4.3.7 Exchange of germplasm in Southern Africa Bean Research Network (SABRN)

Rationale: Some national programs within the SADC region (Angola, south D. R. Congo, Lesotho, Mozambique and Swaziland) still do not have adequate personnel to support breeding programs of their own. The SABRN co-coordinates regional germplasm nurseries and trials, which contain improved lines and released cultivars with the aim of sharing germplasm within the network so that each national program or private sector can benefit from the research that is carried out by others in the region.

Materials and Methods: Various countries within SABRN grouping requested for specific nurseries. These nurseries were organized either by market class, or production constraint or plant growth habit. Such nurseries serve as sources of germplasm with good attributes that might be useful to NARS partners. Table 124 below shows the distribution list of the nurseries in the 2008.

Table 124. List of nurseries and trials that were distributed in the SABRN, 2008 season

Description	No. of nurseries sent	No. of entries	Purpose	Recipient Country
Southern Africa Regional Bean Yield Trial (SARBYT)	13	20	yield evaluation across countries	Angola, Congo Democratic, Lesotho, Malawi, Mozambique Soth Africa, Swaziland, Tanzania, Zambia, Zimbabwe
Southern Africa Regional Bean Evaluation Nursery (SARBEN)	13	100	Adaptation of lines to different environments	Angola, Congo Democratic, Lesotho, Malawi, Mozambique, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe
Bean Improvement for low soil fertility adaptation (BILFA)	1	75	Adaptation to low soil fertility	Angola
Drought nursery –small seeded bean lines	3	135	Evaluation under drought stress	Angola, Swaziland, Zambia
Drought nursery – large seeded bean lines	9	21	Evaluation under drought stress	Angola, Congo Democratic, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zimbabwe
Bean stem maggot lines	8	5	Screening for resistance to BSM	Angola, Malawi, Mozambique, Swaziland
Sugar bean nursery	3	73	Screening for adaptation	Angola, Lesotho, Mozambique
Calima bean lines	2	213	Screening for adaptation	Angola, Mozambique

Table 124. cont´d.

Description	No. of nurseries sent	No. of entries	Purpose	Recipient Country
Navy bean lines	6	45	Screening for adaptation	Angola, Congo Democratic, Malawi, Mozambique, Tanzania, Zambia
Yellow bean lines	2	3	Screening for adaptation	Angola, Congo Democratic
Bio-fortified bean lines fast/track evaluation	4	43	Yield evaluation	Angola, Malawi, Mozambique, Swaziland
Bio-fortified small seeded bean lines	1	72	Yield evaluation	Angola
Bio-fortified large seeded bean lines	3	60	Yield evaluation	Angola, Malawi, Mozambique
Cream/khaki bean lines	3	24	Yield evaluation and adaptation	Angola, Congo Democratic, Tanzania
Angular leaf spot nursery	3	45	Observe reaction to ALS	Angola, Congo Democratic
Medium climbing bean lines	4	13	Yield evaluation and adaptation	Angola, Mozambique
Heavy climbing bean lines	4	30	Yield evaluation and adaptation to lower attitude warmer environment	Angola, Mozambique
TL-I regional bean lines evaluation nursery	2	121	Yield evaluation and adaptation	Malawi, Zimbabwe,
TL-I reference collection evaluation nursery	2	100	Yield evaluation and adaptation	Malawi, Zimbabwe,
TL-II- drought evaluation nursery	2	772	Screening for drought	Zimbabwe, Malawi

4.3.7.1 Southern Africa Regional Bean Yield Trial (SARBYT)

Material and Methods: Each set of SARBYT contained 19 test varieties selected for different attributes, including good yield potential, acceptable grain market types and potential for adaptation to various bean production environments across countries in the SADC region. Each country added a local control to make a total of 20 entries. The trial was laid out in a randomized complete block design with 4 replications and data were collected on rainfall, weather, soil characteristics, diseases and grain yield.

Results and Discussion: During this reporting period many countries in the SADC region experienced bad weather conditions (drought), which adversely affected productivity of the bean crop. As a result many sites were abandoned, and data is reported from a selected few sites. Disease data were collected on angular leaf spot (ALS), common bacterial blight (CBB), ascochyta blight (ASC), floury leaf spot

(FLS), and rust. The ALS disease pressure was highest at Bembeke, Malawi with score rating as high as 8 in some varieties, but there were a few varieties which showed reasonable resistance to ALS with such diseases score ratings of 2-3) on the following varieties: MC12832-129-11, GCI-CAL-172-AR, MN12686-15, CAL143, GCI-LR-171, VTTT923/10-3, MR13557-16-7 and MC13832-129-1. The pressure for CBB was highest at Uyole, Tanzania, where the most susceptible variety had a score of 8. Floury leaf spot was the other disease where some varieties recorded high scores of 8 to 9, at Bembeke, Malawi. In general, a good number of varieties had good resistance to ALS, CBB, ASC and rust, but were susceptible to FLS. The only two varieties which were resistant to all diseases including FLS were: 12832-129-11 and 13832-129-1 (Table 125). Grain yield data showed that Lubumbashi (D. R. Congo), Greytown (South Africa) and Harare (Zimbabwe) were badly affected by drought, and the average site means were less than 1000 kg ha^{-1}, whereas Chitedze and Bembeke (Malawi), Misamfu (Zambia) and Uyole (southern highlands of Tanzania) were less hit by drought and they had better site means, above 1000 kg ha^{-1}. There were 2 carioca varieties (MC13832-129-1 and MC12832-129-1), both with medium seed size, which were among the top yielding varieties across locations. One large red seeded variety (VTTT 924/10-4) also showed good yield potential across sites, with an average grain yield above 1400 kg ha^{-1}, which was similar to the yield of the carioca varieties, and the standard check variety, CAL143. Among the least yielding varieties across locations were those bean varieties which were introduced by ACOS, a commercial firm which exports beans across continents, with the intention of identifying some varieties which could be promoted in SABRN for them to export to Europe. These are the varieties with commercial grain types, which were mostly in cranberry (sugar) and white market classes, but they seem not to be adapted to the environments in most countries, and they are also susceptible to ALS, CBB, FLS and rust in most sites – calling for future breeding activities to incorporate genes for adaptation and resistance to prevalent diseases in the region, into the varieties of commercial value for export to European markets.

Contributor: R. Chirwa

Collaborators: NARIs Bean Research Teams within SABRN; S. Beebe, R.Buruchara, P. Kimani, M.Blair

Table 125. Performance of bean varieties across countries in Southern Africa Bean Yield Trials, 2008.

Identity	Disease Scores											Grain yield kg ha^{-1}								Grain	
	ALS			CBB				ASC	FLS	Rust										Size	Color
	BB	MS	UY	BB	MS	LB	GT	BB	BB	GT	UY	CZ	BB	MS	LB	GT	HR	UY	Mean	(g)	
MC 12832-129-1	2	3	1	1	1	1	3	3	1	1	1	2375	1852	1990	766	822	572	2237	1516	29	Carioca
MC 12832-129-11	2	3	1	1	1	1	3	3	1	1	1	2339	1418	1831	629	661	685	2042	1464	27	Carioca
VTTT 924/10-4	4	3	4	3	1	3	4	3	7	1	1	2319	1437	1796	763	709	995	2083	1450	45	Red
MR 13557-16-7	3	3	1	1	1	1	2	4	5	2	1	2086	1473	1855	635	1200	900	1788	1415	25	Red
CAL 143	2	3	4	1	1	1	4	3	7	2	3	2233	1517	1510	661	750	684	2117	1363	41	Calima
GCI-CAL-172-AR	3	3	5	1	3	1	3	3	7	1	2	2114	1457	1603	706	628	827	1972	1333	41	Calima
CONTROL	4	4	4	3	2	2	3	3	6	3	2	1910	1173	1616	566	1244	561	2004	1316		LOCAL
MN 12686-15	2	2	1	1	1	1	3	3	6	1	1	2062	1088	1776	802	834	523	1926	1287	30	Red
BOUNTY	7	3	6	6	4	2	3	4	7	4	2	1911	700	1521	508	589	884	2135	1238	41	Sugar
VTTT 924/10-7-1-1	4	3	5	1	2	1	3	4	6	2	2	2462	1236	1543	463	616	693	1596	1230	47	Sugar
MR 14215-9	4	4	1	1	1	2	3	3	6	1	1	2124	1363	1462	542	784	671	1601	1217	24	Red
RMA 18	4	3	4	1	3	2	3	3	7	2	1	2056	1226	1568	548	583	593	1785	1209	51	Calima
VTTT 923/10-3	3	4	3	1	1	2	3	2	7	2	2	2260	1120	1256	843	550	713	1585	1180	49	Sugar
RMA 20	4	3	4	3	4	1	3	3	7	1	1	2015	949	1190	714	889	551	1800	1158	44	Calima
GCI-LR-171	3	3	3	1	1	1	2	4	5	1	1	1975	997	1692	516	639	429	1365	1088	42	Red
CRAN BUSH-ARG.	8	3	7	7	6	3	3	4	9	2	5	1969	852	1054	620	689	822	1093	1015	39	Sugar
CANNELIN ARG	8	5	5	5	1	2	3	4	8	4	8	1138	840	1252	643	816	570	1274	969	42	White
CRAN VINE (USA)	4	4	7	3	3	2	4	3	6	6	2	1501	1173	1045	546	522	593	1383	934	51	Sugar
INNER MONG	7	3	4	3	1	3	3	4	9	5	5	1200	766	1098	542	676	703	1108	908	32	Sugar
CANNELIN EGY	8	5	5	7	8	2	3	4	8	6	7	1339	826	972	573	514	736	1129	843	42	White
Mean	4	3	4	3	2	2	3	3	6	2	2	1969	1173	1481	629	736	685	1701	1207		
SE +/-												236	90	264	107	85.9	92	96.1	196		
CV%												23.9	15.3	17.8	32	23.4	27	11.3	23.2		
LSD (5%)												670	258	374	302	244	261	272			

Sites: BB-Bembeke-Malawi, CZ-Chitedze-Malawi,MS-Misafu-Zambia, LB-Lubumbashi-Congo, GT-Greytown-South Africa, UY-Uyole-Tanzania, ZM-Zambia, HR-Harare-Zimbabwe

4.3.8 Varietal releases in Latin America and Africa (2006-2008)

Latin America:

Country	Name	Origin	Year of release
Costa Rica	Chánguena	MR 13652-39 (Bribri x (VAX 1 x RAB 655)	2006
	UCR 55	Línea NJBC-20601-1-CM(71)	2007
Nicaragua	INTA precoz	SRC 2-18	2006
	INTA Seda (Pre-release)	DOR 364 x Rojo Seda	2006

Africa:

Country	Varietal name	Line code	Source	Year of release
DRC (west)	G 59/1-2*	G59/1-2		2008
	VCB 81013*	VCB 81013		2008
	LIB 1*	LIB 1		2008
	Kiangara*	MLV 59/97A		2008
DRC (east)	CODMLV 052*	CODMLV 052		2007
	CODMLV 056*	CODMLV 056		2007
	MLV 224/97A*	MLV 224/97A		2007
	MLV 198/97A*	MLV 198/97A		2007
	MLV 59/97A*	MLV 59/97A		2007
Kenya	E8	New Rosecoco	Local cross	2008
	Lyamungu 85	Chelalang	Tanzania, CIAT line	2008
	AFR 708	Kenya Umoja	CIAT line	2008
	M22	Super Rosecoco	Local cross	2008
	M18	Kenya Red Kidney	Local cross	2008
	L36	Kabete Super	Local cross	2008
	L41	Kenya Wonder	Local cross	2008
	E2	Miezi Mbili	Local cross	2008
	E4	Kenya Early	Local cross	2008
	E7	Kenya Sugar bean	Local cross	2008
	MAC 13	Kenya Safi	CIAT cross	2008
	Kenya Mavuno	MAC 64-1		2008
	Kenya Safi	MAC 13-3		2008
	Kenya Tamu	MAC 34-5		2008
Madagascar	DRK 64	DRK 64	CIAT line	2008 (pre-release)
	UBR (91)45-1	UBR (91)45-1	CIAT line	2008 (pre-release)
	ODR	ODR	Unknown	2008 (pre-release)
	RJ1	RJ1	Local cross,CIAT parents	2008

Country	Varietal name	Line code	Source	Year of release
Madagascar	RI 5-1	RI 5-1	Local cross, CIAT parents	2008
	RI 5-5	RI 5-5	Local cross, CIAT parents	2008
	RI 5-3	RI 5-3	Local cross, CIAT parents	2008
	IL 5-53	IL 5-53	Local cross, CIAT parents	2008
	M 211*	M211		2008
	Kayana*	Kayana		2008
	VNB 81010*	VNB 81010		2008
	RWV 1365*	RWV 1365		2008
	MLV 198/97A*	MLV 198/97A		2008
Rwanda	RWV 1892	RWV 1892		2007
	RWV 2070	RWV 2070		2007
	RWV 1892	RWV 1892		2007
Tanzania	Flor de Mayo	Selian 06	CIAT line	2008
	CAB 19	Cheupe	CIAT line	2008
	Cheupe	CAB 19		2008
Uganda	RWR2075	NABE13	CIAT line	2007
	RWR1946	NABE14	CIAT line	2007
Zambia	KID31	Kabale	CIAT	2007
	C20P30	Kapisha	ZARI	2007
	Kabulangeti	Kabulangeti	Local landrace	2007
Zimbabwe	SUG131		CIAT	2007

Activity 4.4 Development of sustainable seed systems to support wide dissemination

Highlights:

- A strategy of marketing small seed packets as a profitable enterprise is being developed with a private seed company in Kenya and shows great promise for reaching thousands of bean growers.
- An analysis of the effectiveness of training in seed production suggests that participants have significantly improved both technical and communication skills.
- A seed security assessment methodology has found acceptance at the institutional level among important players such as FAO, USAID and important international NGO's.

4.4.1 Increasing Access to New and Existing Technologies

National Bean Research Programmes (NBRPs) and their partners continued to produce and disseminate seed of improved varieties to farmers using different models of seed supply. These models include support to both local seed supply (farmer to farmer-based production, exchange and sale to local market) as well as to integrated local, formal and commercial sector collaborations and enterprises. For instance, in 2008/9 NBRPs in 9 selected countries availed about 181 tones of foundation bean seeds to farmers and commercial seed producers (see Table 126).

Table 126. Amounts of foundation seed supplied by NARS in 9 selected PABRA countries. March 2008-Feb. 2009.

Country	No of varieties	Amount of foundation seed (kg)
Burundi	7	2,560
DRC –Katanga	10	6,230
Ethiopia	14	53,560
Kenya	4	30,292
Madagascar	12	3,150
Malawi	13	5,000
Mozambique	8	2,925
Tanzania	7	75,000
Zambia	7	2,240
Total	82	180,957

Sources: NBRPs annual reports- Presented during ECABREN-SABRN Steering committee meetings Oct. 21-24th, 2009. Lilongwe, Malawi.

4.4.2 Linking Participatory Variety Selection and Impact-oriented seed production and supply systems

Farmers' involvement in a seamless set of activities, from PVS, to subsequent on-farm experimentation and information exchange to seed production and delivery, is creating a strong- impact oriented breeding-to-seed outreach chain. In 36 sites in Malawi where participatory variety selection activities are taking place, farmers followed the PVS with seed bulking of the most preferred genotypes. Generally farmers started on small-scale, for example, with 80 seeds per variety. In Kaluluma Agricultural Extension Programme area in Kasungu, a farmer group (see Figure 63) under the supervision of a government extension agent, has been increasing the selected varieties since 2007. They started with 20 varieties, each with 80 seeds but by 2008 they had produced 120 kg of assorted varieties, and started to share seed with 4 other communities in the same quantities (80 seeds of each variety), following the manner in which they themselves had received initial stocks.

Figure 63. Members of Farm group and their children who received an initial 80 seeds per variety in Dec. 2006 -Malawi-Kasungu (photo taken on 18.10.2008)

In Mozambique, foundation seed is being produced in Mutequelesse and Nintulo, in Gurue, under irrigation. Farmers' Associations and individual farmers of Gurue, Angonia and Tsangano are involved in the production of certified and quality declared seed. A total of four associations with 93 members and 13 individual farmers received the following amounts of foundation seeds of promising and newly released varieties from the NBRP in Mozambique for further increase and supply in their groups and neighborhoods :

- Alto Molocue: 20 kg of SUG 131;
- Gurue: 55 kg of SUG 131 (Nintulo – 30 kg and Ewarelo – 25 kg);
- Malema: 10 kg of PAN 148;
- Gurue (Nintulo): 26 kg of PAN 148;
- Gurue (Nintulo): 40 kg of VTTT 925/9-1-2;
- Angonia (Kanhanja): 60 kg of SUG 131;
- Milange (Sede): 40 kg of PC 1459 BC2-RR9

In south highlands of Tanzania, every site (village) where PVS is taking place each farmer group was given 2 kg, and in addition some selected farmer groups and individuals had planted larger plots: a) Ilembo Peasant Group in Mbozi district planted Uyole 04 and Njano on 4.5 ha, b) J Mwampashi's Ivwanga Group, in Mbozi district planted Uyole 96 on 2.5 ha; and c) a farmer in Kilolo district produced seeds on 2 ha. This PABRA work is linked to a McKnight-funded project.

4.4.3 Marketing of small seed packs

Some NARS have also embarked on innovative seed supply models especially facilitating the marketing of small packs (80, 400 and 2000 g) of certified seeds which are more affordable. Linking through the Tropical Legume-II project, this approach is being tried by CIAT and Kenya Agricultural Research Institute (KARI) in Kenya with Leldet Seed Company in partnership with Farm Input Promotions Africa Ltd (FIPS). The price was Ksh 10, 50 and 200 for 80, 400 and 2000 g respectively (1 USD= Ksh 75) of each the four varieties promoted (Kat B1, Kat B9, Kat x56, and Kat x69). Table 127 illustrates results of sales at one of the promotional marketing sites in Kenya.

Table 127. Size of marketed bean seed packs and the gender of the buyers in Central Kenya (season starting Oct. 2008).

Gender of farmers (buyers)	Seed pack size (g) bought			Total
	80	400	2000	
Female	469	89	7	565 (56.1%)
Male	349	71	21	441 (43.8%)
Total	818 (81.3%)	160 (15.9%)	28 (2.78)	1,006 (100%)

The majority of buyers were women (56.1%) who mainly bought the 80 g pack size (see Figure 64).

Figure 64. Female farmers are the majority of buyers of small seed packs supplied by Leldet Seed Company (Kenya). (Season starting Oct 2008).

The small pack of 80 g was the most preferred by farmers because it was affordable, and with as little money as Ksh 40 =USD 0.50, a farmer can buy certified seeds of each of the four different varieties. Using lessons learned from PABRA dissemination approaches and efforts in Kenya, the Ministry of Agriculture supplied 120 tons of the four Katumani bean varieties (Kat B1, Kat B9, Kat x 56 and Kat x 69) to 50 districts in Kenya. The supply is through farmers' groups as loan to the group and the members take the responsibilities to ensure subsequent farmer-to-farmer exchanges as well as repayment of the seeds loan to other farmers.

4.4.4 Skills and knowledge enhancement

NARS and CIAT scientists continued key training for partner organizations' staff. The training covers aspects related to seed systems namely pre- and post-harvest seed management, seed business including seed supply and dissemination. This seed-related training was supplemented by specific Participatory Variety Selection (PVS) training. For instance, in September 2008, CIAT scientists conducted a Training-of-Trainers ('ToT') course on PVS/seed systems for 23 NARS scientists (breeders and social scientists) from 11countries (see Figure 65).

Figure 65. 3 NARS scientists and technicians involved in a "Trainer of trainers" (ToT) course on PVS/seed systems held in Ethiopia, Sept. 2008.

Some of the scientists have already started using the acquired skills and knowledge. NARS scientists have conducted training for interested staff from partner organizations. In Kenya and Ethiopia, training of trainers was carried out for 147 (52 females and 95 males) extension staff from NGOs, GOs and CBOs. The training covered topics related seed systems (production management, post harvest management, variety evaluation, and seed supply/dissemination at local level). The trained extension staff also imparted the acquired skills to 1670 farmers including 791 women (See Figure 66).

Figure 66. Mr. Nicholas Soikan of Maa Aids Awareness Program (MAAP) in Kajiado, a partner organization to Concern Universal training Masai farmers on bean seed bulking and grain production. Maa is the local Masai language.

As result of this partnership and local capacity building (exposure to new varieties, imparting knowledge and skills in areas of pre and post harvest crop management), beans are being introduced for the first time and are slowly being adopted in communities where the bean crop was unknown, e.g. among some members of Masai communities in Kenya (see Figure 67) who gradually are become sedentary.

Figure 67. Masai Family interested in a new crop (beans) and new varieties with support from MAAP (local NGO) and Concern Universal –Kajiado Kenya (May 2008)

4.4.5 Backstopping to NARS and their partners

Backstopping activities include field visits, support to national planning workshops, and writing seed systems proposals. All these activities are aimed at strengthening PABRA members in seed systems and wider impacts. For instance, a field visit in Cameroon helped scientists from NARS and their partners to understand the existing supply and demand for bean seeds (existing varieties, seed policy, seed sector actors, potential partners in variety promotion, and farmers' and traders' variety preferences –see Figure 68). This will help in laying down strategies to disseminate seeds of the promising and pre–released varieties in Cameroon.

With regard to support to NARS in writing proposals related to seed systems, PABRA scientists assisted NARS in Uganda, Rwanda, D. R. Congo and Zambia. PABRA seed systems team also backstopped several on going PABRA projects on seed systems namely McKnight supported project in Malawi, Mozambique and southern Tanzania, Tropical Legume-II in Kenya and Ethiopia and Alliance for Green Revolution in Africa (AGRA) supported seed systems project in Rwanda (ISAR), Western Kenya (KARI–Kakamega) and Uganda (NARO).

Collaborators: J.C. Rubyogo and L. Sperling

Figure 68. Female farmers on slope of Mt Cameroon showing their interest in climbing bean varieties introduced by IRAD under PABRA support (November 20, 2008)

4.4.6 Some lessons from keys approaches of PABRA to institutional strengthening with NARS and other partner organizations

4.4.6.1 Partnership development

PABRA has had a long and productive history of partnership with diverse stakeholders. The majority of partners are based in-country. The majority of them have common vision, leverage resources to add value to PABRA contribution and allow synergy. This has been documented through the wider impact of bean based technologies across Africa as manifested in improved farmers' livelihoods (Food security, Incomes, Nutrition and health, Community empowerment) and increased capacity for production, marketing, etc

A study on assessing the status of partnership within the PABRA countries was conducted in four countries representing the rest of PABRA members. These countries were Uganda and Ethiopia in ECABREN and Malawi and South Tanzania in SABRN. The study has the following specific objectives:

1. To understand relations between partners - what is working, what is not working and what needs to be improved
2. To map existing network patterns in order to identify which linkages need to be improved
3. To relate partnership process to outcomes
4. To identify gaps and suggest improvement in the future

The partnership was evaluated based on the following elements:

1. Agreement on purpose and shared vision of partnership
2. Engagement and commitment of partners
3. Trust and reciprocity
4. Accountability and decision making
5. Partnership arrangement including legal and institutional arrangement
6. Leadership and effective communication

Key findings and suggestions for improvement include:

- The partnership is very strong in terms of having a shared vision that is agreed on by a majority of the partners in the surveyed countries. Subsequently the roles and responsibilities of the different partners are clearly articulated and understood by most partners. However, the partners do not have agreed norms, approaches and processes for achieving the objectives of the partnerships.

- The partnership has high levels of trust and reciprocity at national level with members indicating high levels of honesty, openness, and willingness to help each other
- The partnership is not strong in terms of partnership arrangements on issues of IPR and resource access
- In terms of accountability and decision making, while this may be clear between the key partners namely CIAT/PABRA/networks, National Bean Programs, it is not as clear within national and local partners.
- Communication across the countries needs improvement, especially the extent to which partnership meetings at national level are held with a frequency that ensures full communication and information sharing as well as providing effective feedback mechanisms between partners.
- Participation of the private sector (apart from seed companies) in the partnership is low in most of the countries.
- There is a multitude of secondary partners (partners of our partners!). There is potential for widening the scope of partnerships through building better links with secondary partners.
- A coherent framework for partnership is needed with clear engagement strategies for different types of partners especially private sector and the secondary partners. However this needs to be strategic in order to balance the need for reach and quality of work.
- A national level forum of partners should be created during which national level works-plans, resource sharing, monitoring and feedback are actualized. This should be included in the coordination mechanisms of the partnerships.
- There should be mechanisms to promote transparency in resource allocation at this level.
- Transparent mechanisms for sharing the success of the partnerships and for individual and collective intellectual property rights including authorship should be developed in a participatory process.

Collaborators: J.Njuki, P. Sanginga and M. Mapira

4.4.6.2 Analysis of the effectiveness of capacity building in PABRA

Rationale: In an effort to strengthen institutional and organizational capacity, CIAT through its Pan African Bean Research Alliance (PABRA) programme, has been running diverse short course trainings in participatory approaches for its partners. During the period between 2003-08, PABRA (in collaboration with its partners) undertook a significant number of training activities aimed at empowering stakeholders with increased knowledge and skills to overcome constraints in technology development, dissemination and use. About 10,556 stakeholders (more than 20% were women) and including the training of trainers, received training in such topics as micronutrient nutrition with bean as the entry point, Participatory variety selection, bean variety development, marker assisted selection (MAS), participatory plant breeding and variety selection, seed systems, bean production, marketing and post-harvest quality assurance, participatory diagnosis, enabling rural innovation (ERI) and gender considerations in research and development, integrated pest and disease management (IPDM), integrated soil and nutrient management, biological nitrogen fixation in legumes, development and design of promotional materials, novel methods in bean research, nutrition, and participatory monitoring and evaluation (PM&E). Forty-eight (48) bean scientists from NARS in the PABRA region enrolled in formal training at M.Sc. and Ph.D. program levels in the areas of cross-border trade, HIV/AIDS and agriculture, agro-enterprise development, community development, bean improvement for disease resistance, molecular and virulence characterization of disease pathogens, participatory research, seed systems and technology transfer. Partners trained included the National Agricultural Research Institutions (NARIs), organizations in the private and public sector, partners from the non - governmental organizations and farmer research groups.

This study was initiated following 5 years of consistent capacity building. The study assessed training provided to national partners in selected areas.

The findings are reported for decentralized seed system and participatory monitoring and evaluation. The study objectives were to assess changes in individuals trained in terms of changes in their knowledge, attitudes, and practice (KAP); to analyze the outcomes of capacity developments at different levels (individuals, institutions and communities); to determine extent of use and adaptation of the approaches by partners; to assess extent of institutionalization and to draw generic lessons and principles for broad application.

Materials and Methods: A semi-structured questionnaire was administered to collect data on: changes in knowledge, attitudes, and practice (KAP) of individuals trained; the outcomes of capacity developments at individual, organization and community levels; target communities; as well as to evaluate the relevance of capacity building activities. The study applied a modified ‘Ripple’ Model as the conceptual framework for assessing change. The Ripple model provides a useful framework to link capacity building activities to outcomes and impacts. Change was assessed at several levels; individual, organization, and target community levels. Data was collected using qualitative and quantitative methods. A modified “Most Significant Change (MSC)” approach was used. MSC is a story based technique that is used to identify and give value to changes that were unintended or unexpected but were nevertheless significant impacts for those involved. Training was defined as an activity that involved theoretical sharing of information and practical interactions intended to develop or impart skills. This kind of learning environment should have taken at least three days for it to be useful to the trainees.

Results and Discussion: The number of people assessed was 39. The respondents had different professional backgrounds that included agriculturalists, social scientists, extension, animal health, environmental management and laboratory technician. Additionally respondents also cut across different positions in the organizations (Table 128)

Table 128. Positions of people interviewed

	PM&E	**Seed Sys**	**Total**
Management	4	8	12
Officers	9	5	14
CDF*	12	-	12
Technician	1	-	1

CDF = community development facilitators

Against a scale, all trainings were rated average, reasons for this rating were that methods used by facilitators utilized a variety of practical and theoretical methods and tools, many stakeholders were involved and training materials given were relevant and adequate. Changes were assessed in two main ways. Respondents were required to rate their knowledge and skills before and after the training using pre-determined variables.

<u>Results from capacity building in PM&E</u>

Results from PM&E indicated that there were significant levels of change in the knowledge and skills on the subject matter covered during trainings (Figure 69). Significant changes were noted in areas of sharing and making use of information, capturing stakeholders’ indicators, periodic reports from stakeholders, presence of functional PM&E plans and frequency of monitoring. Forty two percent (42%) of respondents reported that they had integrated PM&E in other projects. Most commonly integrated aspects in other projects included developing indicators (57%), developing goals and outcomes (27%), and participation by different stakeholders (14%). Only 23% of the individuals trained had implemented PM&E with other organizations they work with. Aspects implemented included determining program outputs and indicators (50%), setting goals and objectives in the form of Monitoring & Evaluation framework for projects (10%) and gender issues (10%).

Organizational benefits related to having PM&E systems were assessed. The results show the following as major benefits; existence of monthly/quarterly project review meetings (31%), regular reporting (12%), clearly defined work plans incorporating PM&E (8%), data collection and analysis (8%) and development of measurable indicators (4%). There were other benefits that accrued from implementing PM&E. They also constituted the various changes happening at organizational level. They include:

- Increased commitment and performance (73%)
- Regular contacts and sharing (53%)
- Improved interaction and sharing (50%)
- Improved technical skills (29%)
- Easy supervision and better understanding of roles (23%)
- Increased transparency (20%)
- Changes in project budgets (7%)

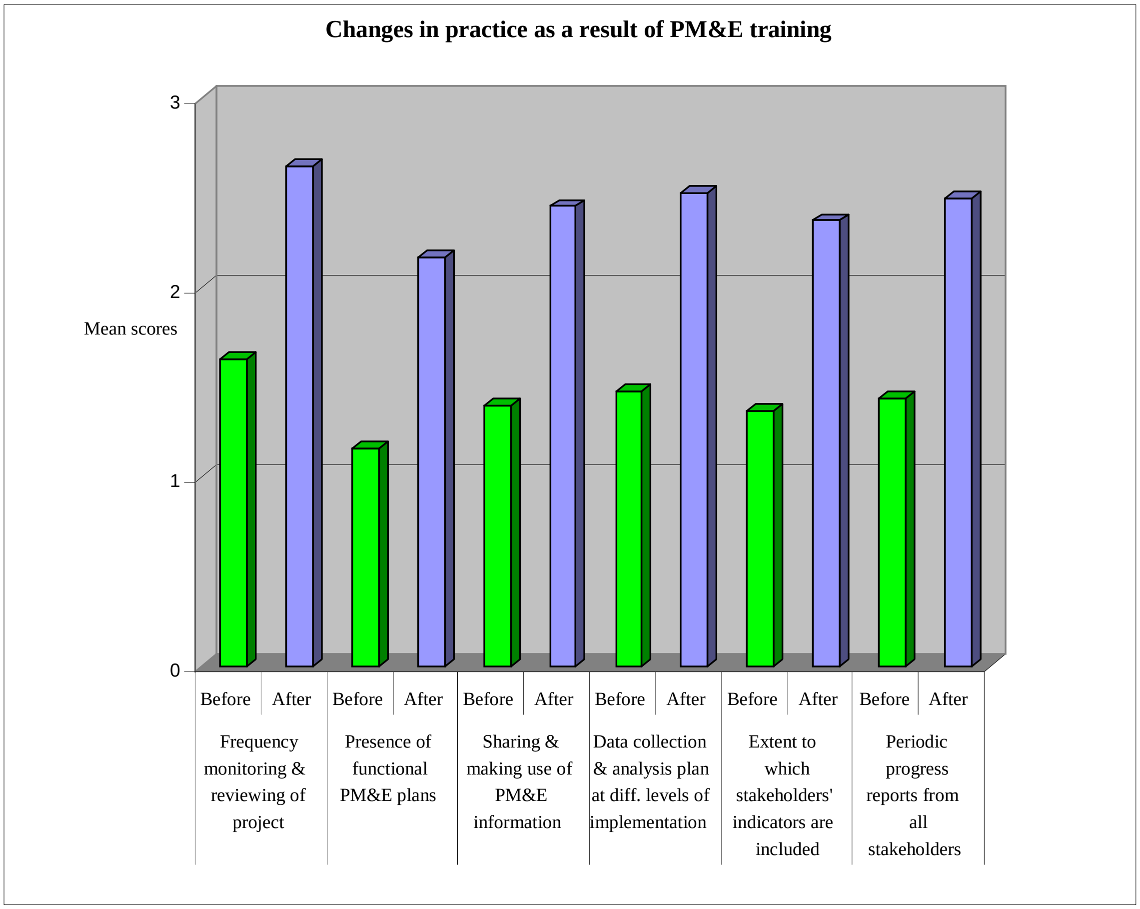


Figure 69. Changes on practice as a result of PM&E training

It can be seen that capacity building has played a major role in facilitating implementation. This is not only in availing capacity but was as well a source of skills for managing stakeholders. Continuous follow up is also a major factor enabling implementation of PM&E.

<u>Results from training in decentralized Seed Systems</u>

Results from decentralized seed system indicate that there were significant changes among trainees in the use of seed manuals, in involving farmers in testing new varieties, involving stakeholders in dissemination and sharing of roles (Figure 70). Respondents gave examples of the changes observed on individuals trained. The list included:

- Increased interaction with communities (92%)
- Use of manuals (39%)
- Improved interaction with NGOs and CBOs (54%)
- Improved interaction with research centers (31%)
- Improved interaction with project managers (77%)

Individuals that had been trained in Seed Systems felt that there were significant changes at community level, which they attributed to the training received. Outstanding changes were noted in the extent to which communities were supporting other communities, there were new partnerships formed, more farmers were getting involved in technology development and dissemination and there was increased sharing of roles and responsibilities (See Figure 70). Additional benefits within communities included the increased number of farmers involved in seed multiplication (33%), the fact that beans were considered a cash crop (20%), and there was increased exchange of seed among farmers (13%). The farmers interviewed listed additional benefits as follows:

- Acquired good agronomic skills (50%)
- Access to fertilizers (17%)
- Access to improved seed (67%)

Farmers attributed these benefits to availability of inputs - seed and fertilizer (50%), trainings (100%) and group marketing (25%). Clearly, building the capacity of the individuals in organizations was translating into benefits for farmers.

Changes at organizational level as a result of training in decentralized seed systems were assessed on the basis of indicators for the integration of the approach at the level of organizations, results were recorded in Table 129.

Preliminary Conclusions

1. Capacity building in participatory approaches has accrued benefits mostly at individual and community levels
2. A gap was defined between individual empowerment and institutionalization
3. The study reveals scarcity in the diversity of methods for training
4. Limitations on follow up on capacity building activities and limited resources

Contributors: E. Lubega, J. Njuki, R. Muthoni, J.C.Rubyogo, P.Mukishi

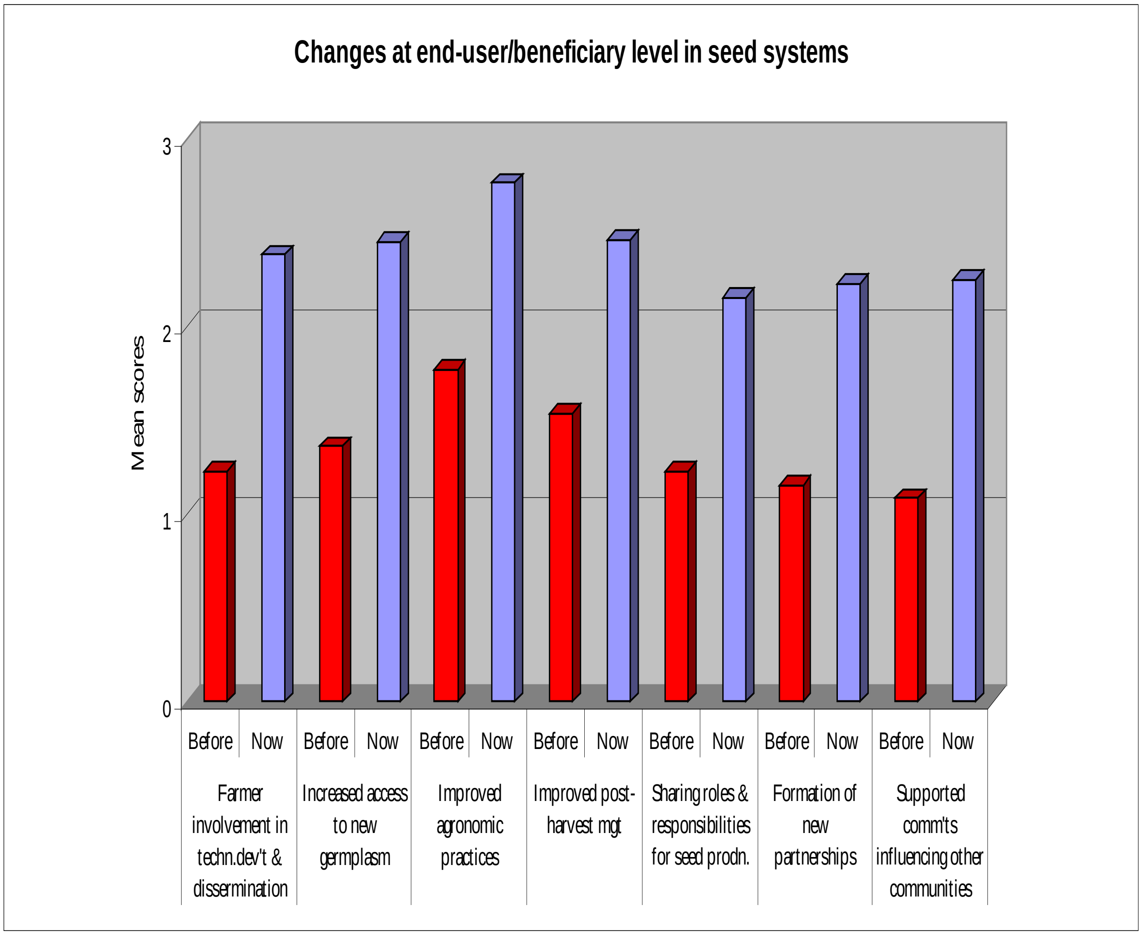


Figure 70. Changes at end user –beneficiary level resulting from training in seed systems

Table 129. Changes at organizational level resulting from training is seed systems

Change in organization	% response
Sharing knowledge with other staff within the organization	100
Use of seed manuals and other extension materials	100
Increased number of staff involved in decentralized seed production systems	92
Management appreciating the importance of engaging many partners in seed production / dissemination	92
Other collaborators/partners outside our organization are adopting decentralized seed production system	85
Increased number of partners/organizations involved in the seed production systems	75
Increase in number of promotion materials produced in partnership with other collaborators	75
New proposals and projects have integrated decentralized seed production systems	75

4.4.6.3 Seed systems

1. In 2003 PABRA initiated a ‘Wider Impact’ Approach (WIP) which facilitates both decentralized (informal and formal) and centralized (commercial) seed actors, to produce and supply bean seeds to farmers. Before the WIP was initiated, seed dissemination of improved bean varieties was limited to farmer research groups, or to areas with a presence of development partners e.g. Non-Government (NGOs) or Government organizations (GOs), schools or through parastatals/seed companies, especially for relief seed supplies. A study which assessed the effectiveness of existing seed systems was carried out in Ethiopia, Southern Tanzania and Uganda was carried out between September and December 2007. The information was collected at five levels along the seed supply chain; NARIs, seed companies and parastatals, partner organizations and seed producers (both individual and farmer groups) and grain producers who were the beneficiaries of the seed suppliers. The study has the following objectives To characterize the existing bean seed systems actors and their roles/responsibilities
2. To assess the bean seed production and supply capacities of decentralized seed producers (farm based systems)
3. To assess the potential and drivers of wider dissemination in decentralized seed systems

Findings about the WIP

1. As result increased awareness, there is a very high demand of improved bean varieties in all the three countries and more particularly where the farmers have been exposed to varieties. When a variety was still new in certain area, farmer seed producers sold its seeds between 50-100 % above the average grain market price. For instance, NABE 12-C in Kisoro (S-W Uganda) was being sold at UgSh 1200/kg and NABE 13 was being sold at UgSh 1500/ kg in Kabale while the average grain bean price was at UgSH was 1500 /kg (1USD= Ugsh 1760). However as these varieties gained popularity and were available in the local market, the price fell to a level of the grain market in about three to four years and their seeds were no longer attracting premium price.

2. The time lag between variety release/official approval and the wider use was reduced from five years to less than one year especially if the varieties have been released or tested in other bean network countries, e.g. as with Roba in southern Tanzania and several varieties in Ethiopia. The situation was different before 2003 (launch of wider impact). For instance Awasha Melka which is very popular variety in Ethiopia was released in 1999; it stayed on the shelf till 2004 when wider impact approach was launched in Ethiopia. However, new varieties released after wider impact was launched were immediately used by farmers. This was due to institutionalizations of wider impact by NARS and the bean industry. Similar results were found in southern Tanzania where pre-released varieties (Uyole Njano, Calima Uyole, Bilfa 4 and Nyeupe Mpya) are being used by farmers. In Uganda regionally adapted varieties e.g. NABE 13 and 14 (root rot tolerant) and NABE12-C (climbing) which are not supplied by any commercial seed companies are widely disseminated in Kabale and Kisoro Districts (south west of Uganda) where NGOs, CBOs and individual farmers played a role in the dissemination.

3. NARS in Ethiopia and Tanzania have developed the capacity to produce foundation seed to supply to strategic partners. For instance, NARS in Ethiopia doubled their breeder seed supply to partners between 2003 and 2007 period from 4 to 8 tones in that period. During this period, the supply of basic seeds also increased from 40 to 110 tones. Also in southern highlands of Tanzania, since 2004, the bean program at Uyole Research Institute has been supplying 10 tones of foundation of new and preferred bean varieties to strategic partners while the Research Farm sells more than 60 tones of certified seeds of released varieties every year on cash and carry basis.

4. The dissemination of improved varieties was more efficient where NARS was engaged in partnership with local service providers e.g. seed company, farmers' organization, and if there was good social and human capital in farmers groups. For instance in Kisoro (south west Uganda) NARO teamed with the Africa 2000 network (a local NGO) and district extension service to disseminate NABE 12C (MAC 31), a variety released in 2003. In 2007 (4 years after the release), the variety was planted on about ¼ of the district areas where climbing beans are grown. The variety represented about 30% of bean grain market in Kisoro District.

5. Commercial seed companies focused on already very popular bean varieties e.g. K132 and NABE 4 in Uganda which were released 1994 and 1999 respectively. However farmer seed producers supplied both locally adapted or site specific (e.g. root rot tolerant) varieties, and widely popular varieties. According to seed company owners, the production and supply of beans seeds is not profitable, unless there is an opportunistic market such as organised massive seed relief distribution by NGOs/GOs. This market represented about 80% of bean seed sold by seed companies in Uganda. More often, farmers did not participate in the bidding processes and their varieties choices were not considered. Some amounts of seeds were likely to be shipped to neighbouring countries e.g. South Sudan and East DRC.

6. The research farm in Agricultural Research Institute (ARI) Uyole which operates commercially though subsidized avails about 60 tones per year of assorted varieties released by the Uyole Bean Programme. This may due to good linkage with the bean programme and the determination to see the varieties released by their institute in the hands of farmers rather than being driven by simple commercial interests as it would be in the case of commercial seed companies.

7. The multiplier effect of training is relatively high among farmers. In addition to seeds, the trained farmer seed producers also are resource people. They trained other farmers in their groups and beyond; passing on information and knowledge on improved varieties while selling seeds and also about improved management practices. Annually, a trainer-farmer was able to train 35, 14 and 72 in Ethiopia, southern Highlands of Tanzania and Uganda respectively.

8. Farm based seed production and or supply increased business opportunities and incomes at either farmer seed producers or local seed traders e.g. in 2007 in Kabale' south west Uganda, there were four agro–input suppliers selling seeds of NABE13 and 14 sourced from the Nyamabale Farmer Field School (a farmer group seed producer). The lowest seed sale by the four agro-input was 2 tones while the highest was 3 tones. Their major clients were farmers who were buying between 0.5 to 2 kg.

9. Farmer based (decentralized) seed production/supply respond to farmers variety needs more than commercial seed sector whose clients are mainly NGOs or GOs relief operations.

10. For improving on their seed business opportunities, farmer seed producers promote their seeds through diverse means –local market, farmer to farmer, and/or local development/church organizations.

11. The majority of farmers of seed producers would like to continue in seed production and supply because they find it to be a source of income, and a very profitable enterprise and that the varieties used were higher yielding than their local ones.

Contributor: R. Muthoni

Collaborators: J.C. Rubyogo and F. Tembo

4.4.7 Development of Seed Security Assessment Methodology

Background

Emergency agricultural assistance seeks to accelerate farmers' recovery from crises such as drought or short-term conflict, aiming to help them continue with crop production, and reduce vulnerability to future stress. Seed aid is the most common example of this type of assistance, and has been extensively implemented; for instance, the FAO alone managed 400 such projects between 2003 and 2005 (FAO, 2005) and, in response to the current food crisis, has seed aid plans for 48 countries. (http://www.un.org/apps/news/story.asp?NewsID=27313&Cr=Global&Cr1=Food)

This type of activity is expanding and involves important sums of money: e.g. Ethiopia has received at least $500 million in emergency seed aid since 1974 (Sperling et al., 2007). Further, 'emergency' seed aid is commonly used to help vulnerable households in *chronic* stress, i.e. the types of populations which public sector agricultural research particularly aims to serve.

Research shows that seed system interventions (seed aid) present serious challenges, and even more so more so during crisis periods. As seed is often replanted, even short-term seed-related interventions can have effects over many seasons. Intervention monitoring and evaluation (M+E) also shows that the dominant design of interventions, from the supply-side, as well as their repetitive nature, (for example in Burundi, 26 seasons in a row) can result in a range of negative effects, skewing crop profiles, undermining local and commercial seed markets, and creating farmer dependencies (McGuire and Sperling, 2008; Sperling et al., 2008).

For all these reasons, it seems illogical (and unwise) that emergency seed-related assistance has received relatively little attention within research circles. CIAT has aimed to help correct this key research gap, by coordinating an active "Seed Systems in Stress" research program since 2003.

The latest research product to emerge from this program is the first-ever 'Seed System Security Assessment Guide' (SSSA). The rationale for the guide, its form, and initial use are summarized below.

4.4.7.1 Distinguishing between Seed security and food security

Farm families are 'seed secure' when they have access to seed of adequate quantity, of acceptable quality, and in time for planting. Helping farmers obtain seed enables them to produce for their own consumption and sale. So fostering seed security contributes to food and livelihood security more generally.

While seed security and food security have some elements in common, they are nevertheless quite different. One can have enough seed to sow a plot, but lack sufficient food to eat – for example, during the 'hungry season' prior to harvest. Conversely, a household can have adequate food but lack access to seed (or the right seed) for planting. This happens more rarely, but can occur if seed stocks kept in the house become infested with insect pests or are otherwise contaminated, or if a disease outbreak requires a switch to a resistant crop variety.

Despite these key differences between food security and seed security, determinations of seed security have nearly always been based, implicitly or explicitly, on food security assessments. Evaluators assess food needs and then just extrapolate seed requirements as part of the aid package. Similarly, they may estimate existing food stocks by measuring harvests or crop losses. If there is a sharp drop in the harvest, they know there will also be a steep decline in food availability. However, this direct link is not necessarily true of seed systems; that is, a production shortfall doesn't necessarily lead to a seed shortfall. For most cereal crops harvests can drop as much as 80%, and seed would potentially still be available.

Ways of calculating seed system needs versus food security needs also differ. We stress the concept of a seed 'system' here since assessments of seed security go well beyond tallying up seed needs on a calculator, although that may be part of the work. Attaining seed security means finding ways to support the systems that give farmers ongoing access to seed of the crops and varieties they require. In many cases, this has little to do with delivering seed directly to farmers and a lot to do with supporting and strengthening the channels through which farmers obtain planting materials on their own.

4.4.7.2 Seed System Security Assessment Guide

The development of a Seed System Security Assessment Guide emerged from the need for agencies to better understand what happens to farming systems in periods of acute stress, but also in periods of chronic, longer term stress. The guide has also been designed to help organizations (NARS, UN organizations, Humanitarian agencies) explore how to take advantage of development opportunities. So the optic of the assessment guide has been to link relief and recovery operations to developmental strategies, from the start.

The challenge of guide development has been to assess the multi-dimensions of seed security *per se*, including issues of seed availability, seed access and seed quality, in the short and long-term. After years of research, CIAT (with partners, particularly Catholic Relief Services) has developed a method for assessing seed security which blends focus on informal and formal seed channels, and which encourages clear thinking about strategic goals. Seed aid entails making a large number of choices around implementation approaches, which have significant implications, but which rarely have been considered explicitly. For instance, should aid aim to restore the system to the *status quo ante*, or to strengthen elements of it (e.g. by introducing new crops, or supporting local markets)? Should interventions focus on the most affected crops, those that generate income, or those that can produce food quickly for recovery? Different goals entail distinct strategies (for instance, women may grow different crops from men, HIV-affected households often have serious labor constraints). Seed systems are complex and dynamic. Interventions need to engage with this complexity if they hope to have lasting impact.

The 'Seed System Security Assessment (SSSA) was designed for the 'lay person' but reflects considerable specialized agricultural and seed system insight. To develop the method, researchers conceptualized the links between harvests and future seed needs and provided tools for practitioners to calculate these links (See Boxes 1 and 2). Further, research had to pioneer methods for analyzing the functioning of local seed markets, versus food markets, as these often serve primary sources of seed in crisis periods (Sperling, 2008).

Box 1. Seed needs from harvests

For a given crop (and variety) and area to be planted, it's easy to calculate the amount of seed a farmer will need for sowing, as well as the size of harvest to be expected.

Let PA be the area to be planted by a farmer, in hectares. Let SR be the seeding rate, that is the amount of seed, in kilograms, that needs to be sown for each hectare of the crop and variety in question. Let MR be the multiplication rate of that crop or variety, namely the ratio of harvestable grain to seed sown. Using these three variables, we can determine sowing needs (SN), in kilograms, for the area to be planted, and the expected harvest (H), in kilograms (some of which may be used in the next cropping season as seed), using a few simple formulas:

SN = PA x SR
H = PA x SR x MR
Thus, H = SN x MR

A note of caution: The formula for SN assumes a crop is sown only once. However, under certain conditions seeds of an initial sowing may fail to germinate. So farmers may end up planting a crop two or even three times, thus doubling or tripling their sowing needs.

Box 2 gives a few examples of seed needs in light of potential harvests of specific crops.

A simple calculator, in Microsoft ® Office Excel format, can be downloaded from [www.ciat.cgiar.org/ Africa/seed_manual.htm].

Here's an example of the inputs and outputs for a hypothetical case.

INPUTS

Parameter	Value	Units
PA	0.5	ha
SR	15	kg/ha
MR	166.6667	ratio
SN		kg
H		kg

Example
0.5
15
166.6667
7.5
1250

OUTPUTS

Parameter	Value	Units	Formula
PA		ha	PA = SN / SR
		ha	PA = H / (SR x MR)
SR		kg/ha	SR = H / (PA x MR)
		kg/ha	SR = SN / PA
MR		ratio	MR = H / (PA x SR)
		ratio	MR = H / SN
SN	7.5	kg	SN = PA x SR
		kg	SN = H / MR
H	1250.0003	kg	H = PA x SR x MR
		kg	H = SN x MR

Box 2. A production shortfall does not necessary equal a seed shortfall

Drawing on basic agronomic knowledge, and refining it with in-the-field reality, we have examined seed needs as they relate to possible harvests. Basically, the per cent of a normal harvest required to meet the sowing needs in the next season is the inverse of the multiplication rate.

As examples, Table 130a shows the basic relationship between harvests and seed need in two crops in Mali, factoring in farmers' seed sorting and re-sowing rates for this semi-arid context. Table 130b, moves towards greater precision, drawing on actual field data: for a higher and lower potential area in Ethiopia, and contrasting a good versus bad harvest year. The message from both these tables is consistent that a *production shortfall is not necessarily equal to a seed shortfall.* For many crops analyzed in African contexts (for example, common bean, faba bean, maize, sorghum, groundnut, wheat, tef) harvests can drop as much as 80-90%, and enough seed is potentially available. We add the qualifier 'potentially' as the quality of seed harvested has to be adequate and farmers have to be able to save sufficient stocks until sowing time. This may be particularly challenging in regions with just one agricultural season per year.

Table 130. Sowing needs in relations to harvests , by household

a. Example from Northern Mali

Crop	**Pearl Millet**	**Groundnut**
Sowing needs (kg/ farmer area; sorting and resowing factored in)	10-20	15 kg (1/4 ha)
Harvest (on normal farmer area)	430	125 kg (1/4 ha)
Per cent of harvest needed for seed	**3.4**	**12.0**

b. Example from Eastern Ethiopia

Crop	**Sorghum Chiro (highland)**	**Sorghum Miesso (Lowland)**
Surface Area per Household	1/2 ha.	3/4 ha
Sowing needs (kg– for area)	7-8	11-12
Harvest/yield (good year)	1250 kg	1600 kg
Per cent of harvest needed for seed : good year	**0.56 to 0.64**	**0.75**
Harvest/yield (bad year)	400 kg	260 kg
Per cent of harvest needed for seed :bad year	**2.0**	**4.6**

As a brief overview, the guide presents a seven step method for understanding seed systems during a crisis and its aftermath, and for identifying what seed-related assistance is needed. It walks the decision maker, relief worker, research through a series of discrete steps. These include analysis of the effects of the disaster on seed systems, identification of possible problems to be addressed, and choice of actions to alleviate the constraints identified.

More specifically, the guide is structured to:

1. Identify zones for assessment and possible intervention.
2. Describe the normal status of the crop and seed systems.
3. Describe the broad effects of the disaster on these farming systems.
4. Set goals for agricultural relief and recovery operations based on farmers' needs.
5. Assess the post-crisis functioning of seed channels to determine whether short-term assistance is needed.
6. Identify any chronic stresses that require longer-term solutions and identify emerging development opportunities.
7. Determine appropriate short- and longer-term responses based on the analysis of priority constraints, opportunities, and farmer needs.

Steps 5 and 7 merit special mention

Step 5, assessing the functioning of seed channels during a period of stress, is at the heart of the guide. Step 5 leads the assessor through different loops to understand how home production and social networks are functioning during a crisis and in the stressful aftermath; how the local seed and grain markets are holding up or have changed under stress; and possibilities for tapping into the formal seed sector and commercial supplies. These different types of seed channels need to be assessed and then their joint potential for meeting farmers' needs evaluated.

Step 7 matches responses to the situation. It provides decision trees for examining possible interventions and discusses when they may or may not be appropriate. Box 3 gives an example of one decision-making tree. In the accompany text, we focus only on variety quality. (See Sperling, 2008, for full narrative).

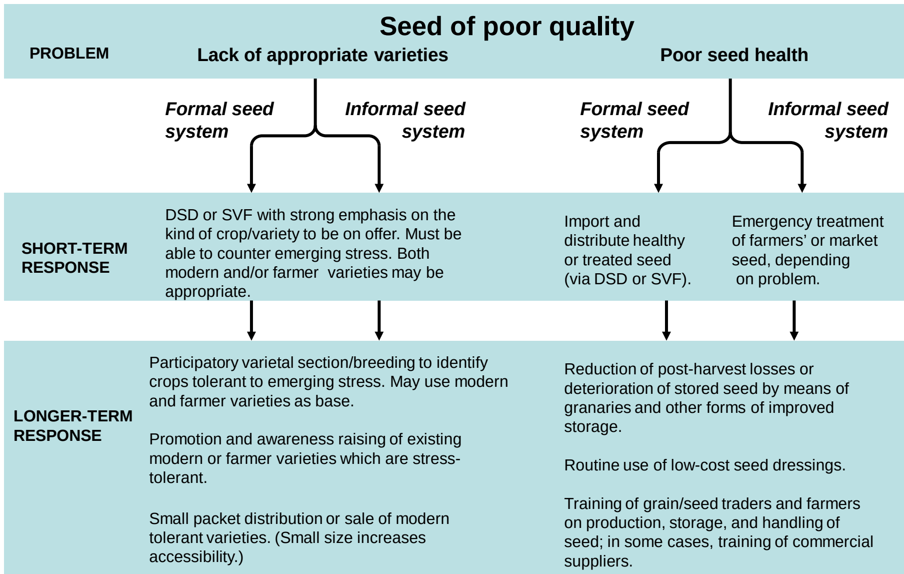
4.4.7.3 SSSA Uptake - International Public Good, Responding to Demand

The Seed System Security Assessment (SSSA) Guide was published August 2008. It is readily available on line as well: http://www.ciat.cgiar.org/africa/seed_manual.htm It has proved useful for a range of users (the UN, governments, humanitarian agencies, research organizations), and represents a broadly demanded International Public Good (IPG). In terms of reaching varied constituencies, the follow actions have taken place:

- USAID (US Government) has posted it on its website. This organization is among the biggest seed aid donors in the world.
- The guide has been recommended as *the* seed security assessment guide in the UN Food and Agriculture Organization (FAO) Seed Unit's study for the upcoming 'State of the World on Plant Genetic Resources.' The FAO Emergency Unit (TCE) is among the leading global advisors on emergency response.
- The guide has been reported on several wide-reaching NGO and humanitarian practitioner websites: e.g. ReliefWeb, Catholic Relief Services, and Drylands Coordination Group (Norway).
- The guide has also been picked up by several prominent knowledge management groups: Eldis, CTA, SPORE, and UNESCO's OpenTraining Programs.

Hard copies are also being distributed via CIAT, USAID/Government, the FAO and CRS.

Box 3: Decision tree for options to respond to problems of poor seed quality



Variety quality: Farmers do not often experience short-term problems of variety quality, that is, shortages of varieties adapted to their overall conditions. Of course there are cases where crops or specific crop varieties suddenly seem 'unadapted' because of marked disease or pest build-up – as with cassava mosaic virus, or root rots in beans, or infestations of the parasitic weed striga in maize and other cereals. More often, short-term concerns over variety quality arise when implementers sense that a potentially useful modern variety, not yet available to farmers, could be made available, and quickly, via emergency aid. Curiously, then, this concern comes not from a 'problem', but from the identification of a potential opportunity.

In the face of a significant environmental stress, and the need for a short-term response to it, implementers must be careful that what they offer is indeed adapted to the emerging situation. Whether the materials on offer are farmer varieties or improved varieties, they should have been previously tested or grown under the specific conditions now at hand. A cautious but useful approach is to promote a basket of varieties. In the face of *ad*versity, *di*versity can be the key to encouraging production stability.

Over the longer term, farmers may need novel materials, either modern varieties or ones from other local farming systems, to allow them to respond to shifts in their cropping system. These may have been made necessary by environmental changes (like atmospheric warming), rising disease and pest incidence, or inappropriate promotion of unadapted modern varieties. In some cases, farmers may not be able to maintain the levels of purity they desire in their own saved seed or that from the market. So the introduction of local (i.e., nearby) varieties may also contribute to reinvigorating the gene pool farmers' rely on.

In the case of popular or well-known varieties already in use, implementers may wish to concentrate on promotion: making farmers more aware of the varieties, packaging or selling them in user-friendly quantities, and putting them on offer at agricultural and other events. In some instances varietal development (plant breeding, selection, and field trials) may be necessary. Farmer participatory models should be considered for this R&D, especially where growing conditions are stressful. Collaboration between farmers and formal breeders ensures that the varieties eventually selected will actually grow under real production conditions, including farmer management practices, and that they meet local cultural, social, and economic preferences.

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Activity 4.5 Socio-economic activities

Highlights:

- A baseline study to determine the role of beans in drought prone areas of eastern Kenya has been completed. Beans are the second most important food after maize and are critical for food security.

4.5.1 Targeting crop breeding and seed delivery efforts to enhance the impact on the livelihoods of the poor in drought-prone regions of sub-Saharan Africa

Rationale: The Tropical Legumes-II (TL-2) Project coordinates efforts across six legumes (common bean, graoundnut, cowpea, chickpea, pigeonpea and soybean) to improve the genetic adaptation of these to drought prone areas. With each crop there is a component of social science to establish a baseline description of the target area, and to characterize the role of legumes and the producer and consumer varietal preferences in these areas. The bean component focuses on eastern Kenya and two regions of Ethiopia, and will be closely coordinated with both the seed component and the Participatory Varietal Selection within the same project.

Materials and Methods: The major activities of the socio-economic studies inn this component of the project include: 1) regional situational and outlook analysis and baseline studies and 2) the assessment of end-user preferred traits in support of bean breeding and delivery efforts through gap analysis and participation in PVS activities and early adoption studies (in few sites where variety uptake is significant). 3) Targeting for up-scaling: reaching vulnerable groups and mapping of broader impact target domains and 4) capacity building for NARS partners.

4.5.1.1 Regional situational and outlook analysis

During the period of reporting, a regional situation and outlook was drafted and shared with scientists in CIAT and NARS, both for peer review and use. A copy of the draft was also sent to the TL-2 Global project manager. The report has also been submitted to CIAT communication and publication unit at Cali for publication on the CIAT website. The regional situational and outlook analysis was conducted in 2008 for four countries from the Eastern and southern Africa targeted for TL-2 project (i.e. Ethiopia, Kenya, Malawi and Tanzania). The report covered the aspects of variety distribution, production trends, utilization, domestic use and trade; market preferred traits, available common bean technologies and their adoption and institutional constraints and outlook for common bean. Data used for this analysis was from reports of the existing surveys conducted in these countries; annual national reports and archived FAO statistics on production and trade statistics (1970-2004). This report is currently undergoing review process and will be published on the CIAT website soon.

4.5.1.2 Socio-economic baseline surveys

A socio-economic baseline survey was conducted between June and December 2008 in Eastern province of Kenya, and in Oromia and Southern region of Ethiopia. Eastern Kenya and Oromia region in Ethiopia represent semi-arid, mid-altitude (1000-1500 masl) while SNNP is semi-arid high altitude bean production environment (Wortmann et al., 1998).

These socio-economic surveys adopted an approach that accounts for conditions with and without as well as before and after the project and is part of an overall monitoring and evaluation framework aimed at measuring and attributing the short- and long-term impacts of the TL-2 project. The survey involved focus group discussions in the selected communities, individual households interviews and interviews of key informants in the grain markets. The interviews were complemented with transact walks through the selected villages to make direct observations on the farming systems and constraints. The household survey questionnaires were developed to gather data on: (1) basic farm and household characteristics; (2) cropping patterns, input use, production, and yields; (3) gaps between research, extension and farmers; (4) vulnerability (drought, pests, diseases, and prices) and coping strategies; (5) gender roles in input supply, food production and marketing and women's access to productive assets and financial resources; (6) adoption of common bean varieties and dis-adoption of bean varieties as well as variety trait preferences; and (7) bean seed systems. In addition to the questionnaires, other supporting tools included improved and local seed samples and GPS equipment.

A total of 360 farming households selected from 18 villages in the two countries and 120 traders along the value chain (i.e. small collectors, big collectors, retailers, wholesalers, exporter/processors and consumers) in Ethiopia and Kenya were interviewed. Ten markets including Shashamene, the biggest market, were surveyed in Southern region and Oromia in Ethiopia; while five markets from eastern Kenya and one big market, Nairobi, were studied in Kenya (Table 131). In each market common bean varieties were recorded and key informant interviewed.

Table 131. Geographical spread of the surveys

Description/Country	Total No. of districts	Number of village/markets	Number of households/traders
Survey of farming households			
Ethiopia	4	12	240
Kenya	2	6	120
Market surveys			
Ethiopia	2	10	60
Kenya	2	5	60

Data entry has been completed for all 360 sampled households and data entry for the market studies questionnaires is in progress. Of the 360 entered data, 120 taken from Kenya have been fully cleaned and the analysis of this data is in progress. The results from the analysis so far, indicate that farmers in Eastern Kenya engage in a diversity of crops, cropping systems and diverse distinct farming management practices that are integrated with local ecosystems and livelihoods to cope with drought. They dry plant their crops, make terraces to harvest water, intercrop intensively, keep livestock, invest in social capital, work outside their farms for food or wage and undertake petty trade and handcraft but still cannot meet their food requirements the whole year round. On average, each household experiences 5 months of inadequate food supply per year. Drought is ranked the most important constraint to livelihood improvement, causing about 70% yield loss in common beans when it occurs. Nevertheless, common bean is ranked as the second most important food crop after maize, with about 70 percent of the household surveyed growing it primarily for home consumption. Consistent with the existing literature, data from eastern Kenya reveals a great diversity of common bean varieties at community level with each farmer growing about 3 varieties simultaneously on the farm but with as many as 10 varieties on some farms. Popular varieties include GLP2 (allocated 21% of bean area) Mwitemania (allocated 30 % of the area) and KatB1. Household characteristics, as well as variety consumption and production attributes are the driving factors that underlie variety choice and extent of planting. Market imperfections continue to induce farmers to select varieties they would prefer to eat even when such varieties are rated low for drought tolerance. Current trade-offs between consumption and production attributes are very small demonstrating that farming households value both attributes highly and they will be less likely to accept big trade-offs. The implication for the breeding effort is to target to improve both categories

4.5.2 Capacity building of enumerators for baseline study

Non-degree training of enumerators was through the surveys. However, special sessions were always held at the beginning of each survey to train enumerators on the questionnaire, the art of interviewing covering establishing rapport and probing, as well as GPS reading. In total five such training sessions were organized at different times and venues (namely in Nazereth, Siraro woreda, and Dale woreda in Ethiopia, and Kari-Katumani in Kenya) during the reporting period. A participatory approach was used to facilitate sharing of experience, to stimulate discussions and to enhance learning. Nineteen trainees attended from: the Melkassa agricultural Research Center; IPMS (an NGO partnering with Awassa Agricultural Research Center and CIAT in seed systems and PVS activities); and government extension offices in the study areas.

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Based on Seed AID work of L. Sperling, Tom Remington and other partners

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Reuters (Nature….) (which linked to Science)	Agricultural Biodiversity Blog
Broadcast	Andhranews.net (India)
BBC Network Africa	DailyIndia.com
South African Broadcasting Corporation (SABC)	KTIC Rural Radio Online
Channel Africa	*Malaysia Sun* Online
Print	*Nature* News
Hindustan Times (India)	NewKerala.com (India)
New Vision (Uganda)	Star Online (Malaysia)
Bistandaktuelt (Norway)	Thaindian.com (India)
	TopNews.in (India)
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Editorial contributions

I.M. Rao served on the scientific committee of the editorial board of the journal, Agronomia Colombiana, and a reviewer to the journals: Crop Science, Agroforestry Systems and Acta Agronomica.

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Ministerio de Agricultura - Instituto Nacional de Investigación Agraria (INIA), Peru
UDENAR - Universidad de Nariño, Facultad de Ciencias Agrícolas, Pasto, Colombia
Universidad Nacional de Colombia

Partners Collaborating with Headquarters

Ing. Oscar Vizgarra, EEA “Obispo Colombres”, Tucumán, Argentina
Dr. Teresa Fowles, University of Adelaide, Australia
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Dr. Alain Goossens, University of Ghent, Belgium
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Dr. Roseline Remans, Centrum voor Microbiele, Belgium
Ing. Hernán Campos, CIF “La Violeta”, Cochabamba, Bolivia
Ing. Ruddy Meneses Arce, CIF “La Violeta”, Cochabamba, Bolivia
Ing. Juan Ortubé, Instituto de Investigaciones Agrícolas “El Vallecito”, Santa Cruz, Bolivia
Ing. Carlos Rivadeneira, Universidad Autónoma Gabriel Rene Moreno, Santa Cruz, Bolivia
Ing. Tito Anzoátegui, Instituto de Investigaciones Agrícolas “El Vallecito”, Santa Cruz, Bolivia
Ing. Teresa Avila, Centro Fitoecogenético Pairumani, Bolivia
Dr. Gonzalo Avila, Centro Fitoecogenético Pairumani, Bolivia
Ing. Ximena Reyes, Centro Fitoecogenético Pairumani, Bolivia
Dr. Maria Jose. Peloso, EMBRAPA-Centro Nacional de Pesquisa Arroz e Feijao, Brazil
Dr. Rosana Brondani, EMBRAPA-Centro Nacional de Pequisa Arroz e Feijao, Brazil
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Dr. Alberto Pradilla, Universidad del Valle, Cali, Colombia
Dr. Oscar Checa, University of Nariño, Pasto, Colombi
Universidad Nacional de Colombia, Palmira, Colombia
Dr. Gustavo Ligarreto, Universidad Nacional de Colombia, Bogotá, Colombia
Dr. O. Oliveros, Universidad Nacional de Colombia, Bogotá, Colombia
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Dr. Ramón Garza, INIFAP, Texcoco, México
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Dr. Gina Hernández, Universidad Autónoma de México, México
Mrs. Celestina Nhagupana Jochua, IIAM, Maputo, Mozambique
Mr. Magalhaes Amade Miguel, IIAM, Maputo, Mozambique
Ing. Aurelio Llano, INTA/CNIA, Managua, Nicaragua
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Dr. Oscar Gómez, UNA, Nicaragua
Ing. Emigdio Rodríguez Quiel, IDIAP, David, Chiriquí, Panama
Dr. Gruneberg, Wolfgang, CIP, Peru
Dr. Thomas ZumFelde, CIP, Peru
Ing. Angel Valladolid, INIA, Lima, Peru
Ing. Miriham Gamarra, INIA, Lima, Peru
Dr. James Beaver, University of Puerto Rico, Mayaguez, Puerto Rico
Dr. Deidre Fourie, ARC-Grain Crops Research Institute, South Africa
Dr. Merion Liebenberg, ARC-Grain Crops Research Institute, South Africa
Dr. Bill Broughton, University of Geneva, Switzerland
Dr. Emmanuel Frossard, ETH University Zurich, Switzerland
Eng. Joseph Ndunguru, Plant Protection Division, Tanzania.
Dr. Bonnie McClafferty, HarvestPlus, IFPRI, Washington D.C., USA
Dr. Howarth Bouis, HarvestPlus, IFPRI, Washington D.C., USA
Dr Ross Welch, USDA, Cornell University campus, USA
Dr Ray Glahn, USDA, Cornell University campus, USA
Dr. M. Grusak, USDA, USA
Dr. T. Porch, USDA, USA
Dr. Mark Brick, Colorado State University, USA
Dr. Henry Thompson, Colorado State University, USA
Dr. Theresa Fulton, Cornell University, USA
Dr. Steve Kresovich, Cornell University, USA
Dr. James D. Kelly, Michigan State University, USA
Dr. Jonathan Lynch, Pennsylvania State University, USA
Ing. María Elena Morros, INIA, Estado de Lara, Venezuela

Ing. Miguel Pérez, INIA, Maracay, Venezuela
Ing. Ramiro de la Cruz, INIA, Estado de Lara, Venezuela.
Dr. Godwill Makunde, Crop Breeding Institute, Zimbabwe
Mr. Walter Manyangarirwa, Africa University, Zimbabwe

Institutional Partners in Africa

National Research and Extension Programs: Democratic Republic of Congo, Ethiopia, Burundi, Rwanda, Uganda, Kenya, Tanzania, Sudan, Madagascar, Malawi, Zimbabwe, Lesotho, Mozambique, Republic of South Africa, Swaziland, Angola, Zambia.

Universities: Country

Country	
D R Congo	• University of Lubumbashi
Kenya	• University of Nairobi
	• Moi University
Malawi	• University of Malawi – Bunda College of Agriculture
Mozambique	• University of Mondrane
Norway	• Norway University of Life Sciences
South Africa	• University of Free State
	• University of Pretoria
	• University of KwaZulu Natal
Swaziland	• University of Swaziland
Tanzania	• Sokoine University of Agriculture
The Netherlands	• Wageningen University
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United Kingdom	• Overseas Development Group/University of East Anglia
Zambia	• University of Zambia
Zimbabwe	• University of Zimbabwe
	• Africa University
	• Midland University

NGOs: Country

Country	
Angola	• World Vision International -WVI
D R Congo	• World Vision International -WVI
	• National Seed Company
	• 13 Community Based Organizations
	• Association des Producteurs de Semences de Katanga (APSK)
	• PRODEL (local NGO)
	• Church based organizations
Ethiopia	• Catholic Relief Services
	• Self Help Development International
	• CARE
Kenya	• Rural Farm Alternative Organization
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	• Nargina Social Work Group
	• Concern Universal
Lesotho	• Participatory Ecological Land Use and Management (PELUM)
	• US Canada

	• Glo
Malawi	• World Vision International-WVI
	• Concern Universal –CU
	• Plan International
	• Harvest Help and Find your Feet
	• CARE International
	• Concern World Wide
	• Canadian Physician for Relief and Development (CPAR)
	• Small Holding Coffee Trust Funds
	• Action Aid
Mozambique	• World Vision International-WVI
	• CARE International
	• Concern Worldwide
Rwanda	• CARE
	• World Vision International-WVI
Swaziland	• World Vision International-WVI
Tanzania	• Action Aid
	• Adventist Development and Relief Agency –ADRA
	• Agric. Development Trusts in Mbeya
	• Catholic Relief Services
	• Lay Volunteers International Agency and Christian Council
	• Mbozi, Ileje and Isangati Consortium/foundation (MIICO)
	• Save the Children
	• VECO
Uganda	• AfriCare
	• CARE
	• World Vision International-WVI
	• CARE International
Zambia	• Plan International-Zambia
	• Lutheran World Foundation
	• Harvest Help (UK)
Zimbabwe	• Zimbabwe Farmers' Union

<u>CBOs</u>: in more than 14 countries.

<u>Regional Institutions:</u> ASARECA, Food, Agriculture and Natural Resources (FANR), CORAF.

<u>Private Sector</u>:

Country	Company
Kenya	• Lagrotech Seed Co
Lesotho	• PANNAR
Madagascar	• CTHA
Malawi	• Demeter Farm
	• SeedCo-Malawi
South Africa	• PANNAR
Swaziland	• Umlimi Lokhomile Seed Co
	• PANNAR
Tanzania	• Dodoma Transport Agency Ltd
	• Masware Farm Seed Co

Zambia	• Kamano Seed Co • Sunnyside farm
Zimbabwe	• Pristine Seeds • Progeny Seeds • PANNAR • Seed Co

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Other CGIAR centers and programs: AHI (ICRAF), ICRISAT, IPGRI, WARDA, IRRI, CIMMYT.

Others:

Tanzania	The MEDIAE Company FAIDA-MALI Himo Environment Management Trust (HEM)
Italy and Ethiopia	Food and Agriculture Organizations (FAO), UN agency

List of NARS and Collaborating Partners in Africa

Country	Name	NARs
Angola	Salvador Miguel Antonio Chicapa Dovala	Instituto de Investigacao Agronomica
Burundi	Dismas Nsengiyumva	ISABU, Bujumbura
D.R. Congo	Lubobo Kanyenga Mbikayi, Nkoko Lunze Lubanga	INERA Kipopo INERA, PNL, Mulungu INERA, PNL, Mulungu
Ethiopia	Teshale Assefa Asrat Asfaw Amele	EARO-NARC, Melkassa Ethiopia Institute of Agricultural Research (EIAR) Southern Agricultural Research Institute (SARI) Amhara Agricultural Research Institute (ARARI) Tigray Agricultural Research Insitute (TARI)
Kenya	David Karanja	KARI, Machakos
Lesotho	Simon Bereng	Agricultural Research Department
Madagascar	Herimihamina Andriamazaoro	DRA, FOFIFA
Malawi	Charles Kapapa Elisa Mazuma I. Fandika A. Mwakikunga Dr Sleshe James M. Bokosi Edward R. Shela B.J.V. Msukwa Lizzie Shumba Edson Musopole Alfred Kambwiri Jimmy Demitri	Chitedze Research Station Department of Agricultural Research Services Kasinthula Research Station Chenachena Sub Research Station ICRAF Bunda College of Agriculture, University of Malawi Northern Corridor Ministry of Agriculture Ekwendeni Hospital Action Aid Care International Demeter Farm
Mozambique	Manuel Amane Maria Jonase Patricio F. Benito Nuria Chavez Francisco C. Edwardo	Instituto de Investigacao Agraria, IIAM, Maputo Lutheran World Federation APLA District Department of Agriculture DDA Tsangano
Rwanda	Augustin Musoni,	ISAR-Rubona, Butare
South Africa	Andries Liebenberg Deidre Fourie Antony Jarvie	Agricultural Research Institute Council – Grain Crops Institute (ARC-GCI) PANNAR Research Services Pty (LTD)

Country	Name	NARs
Sudan	Elsadig S. Mohamed	Wad Medani
Swaziland	Zodwa Mamba	Agricultural Research Division
Tanzania	Catherine Madata	Agricultural Reserarch Institute
	Festus Ngulu	SARI, Arusha
	Zainabu S. Majubwa	ADP-Mbozi
	Benson J. Minja	LAELA Agriculture Centre
	Shila Mwashala	Caritas
	Mollo Prison Farm	
	Rhodes Family Farm	
	K.K.K.T. Church	
	Isangati Agriculture Development Organization	
Uganda	Michael Ugen	NAARI, NARO
Zambia	Kennedy Muimui	Zambia Agricultural Research Institute
	Horemans Desire Frans M	KAMANO Seed Company Ltd
	Kanenga Kennedy	Food Legume Research Program
	Geoffery Kayama	Self- Help Africa
	Aubrey Chulu	Plan –Zambia
Zimbabwe	Godwill Makunde	Crop Breeding Institute
	Cain Manzira	Crop Breeding Institute

Project Staff List

Senior staff

Beebe, Stephen, PhD, Breeder, Geneticist, Bean Project Manager
Blair, Matthew, PhD, Germplasm Characterization Specialist/Bean Breeder
Buruchara, Robin, PhD, Plant Pathologist, CIAT-Africa Coordinator (stationed in Kampala, Uganda)
Chirwa, Rowland, PhD, Plant Breeder/SABRN Coordinator (stationed in Lilongwe, Malawi)
Kimani, Paul, PhD, Plant Breeder for ECABREN (University of Nairobi/CIAT) (stationed in Nairobi, Kenya)
Morales, Francisco, PhD, Virologist (now has left CIAT)
Muthoni, Rachel, BSc, MPA, Monitoring and Evaluation Specialist, (stationed in Kampala, Uganda)
Njuki, Jemimah, PhD, ERI Specialist, (previously stationed in Zimbabwe; now has left CIAT)
Nyang'aya, Martha, MSc, Nutrition (stationed in Kampala, Uganda)
Pyndji, Mukishi, PhD, Plant Pathologist, ECABREN Coordinator (previously stationed in Arusha, Tanzania; now has left CIAT)
Rao, Idupulapati, PhD, Plant Nutritionist/Physiologist
Rubyogo, Jean Claude, BSc., Seed System Specialist (stationed in Malawi)
Sperling, Louise, PhD, Social Scientist, (stationed in Rome, Italy)

Postdoctoral Fellow

Katungi, Enid, PhD, Agricultural Economics (stationed in Kampala, Uganda)
*Rangel, Andres F., Plant Nutrition and Physiology

Administrative staff

Administrative staff gives support to all CIAT Africa staff at each location regardless of the project they belong to

Bakulama, Samuel (stationed in Kampala, Uganda)
Basemera, Jolly, Administrative Assistant, B.A.M.A. (stationed in Kampala, Uganda)
Dossi, Susan, Administrative Assistant (stationed in Lilongwe, Malawi)
Gambo, Abdalla, Security Guard (stationed in Arusha, Tanzania)
Giraldo, Isabel Cristina, Economist, Administrative Assistant, CIAT-Bean Project Manager
*Gondwe, Zifa, Driver (stationed in Lilongwe, Malawi)
Kauwa, Anthony, Driver/Mechanic (stationed in Lilongwe, Malawi)
*Mawanda, Limani, Office Assistant (stationed in Lilongwe, Malawi)
Magombo, Sinosi, Office Assistant (stationed in Lilongwe, Malawi)
Mkagula, Peter, Driver (stationed in Lilongwe, Malawi)
Nassozi, Sarah, A.C.I.S., Regional Finance and Administration Officer (stationed in Kampala, Uganda)
*Ngondo, Ella Administrative Assistant (staioned in Lilongwe, Malawi)
Ngwira, Evelyn, Accounts Assistant (staioned in Lilongwe, Malawi)
Shirima, Julita, Office Assistant (staioned in Arusha, Tanzania)
Travas, Betty, Administrative Assistant (staioned in Arusha, Tanzania)
Yoasmu Mugarura (stationed in Kampala, Uganda)

Research associates and assistants

Acam Catherine, Lab Technician (stationed in Kampala, Uganda)
Astudillo, Carolina, Biol. Germplasm Characterization Lab.
Buah, Stephen, MSc, (stationed in Kampala, Uganda)
Buendía, Héctor Fabio, Ing. Agr., Germplasm Characterization Lab.
Bueno, Juan Miguel, Ing. Agr., M.Sc., Entomology
Cajiao, César, Ing. Agr., Mesoamerican Bean Genetics
Caldas, Gina Viviana, Chem., Germplasm Characterization Lab.
Castaño, Mauricio, Ing. Agr., Virology Research Unit
Cortés, María Luisa, Ing. Agr., M.Sc., Mesoamerican Bean Genetics
Galeano, Carlos Hernando, Ing. Agr., Germplasm Characterization Lab.
Grajales, Miguel Angel, Agric., Tech., Mesoamerican Bean Genetics
Jara, Carlos Eduardo, Ing. Agr., M.Sc., Phytopathology

Kalolokesya, Lizzie, Bean Breeding (staioned in Lilongwe, Malawi), on study leave
*López, Hernán, Biol., Germplasm Characterization Lab.
Lubyobera John, Lab attendant, (stationed in Kampala, Uganda)
Magaleta, Ruth (stationed in Lilongwe, Malawi), on study leave
Maina, David (stationed in Nairobi, Kenya)
Male Alan (stationed in Kampala, Uganda)
*Medina Zapata, Juliana Ines, Biol., COLCIENCIAS Researcher
Monserrate Fredy Alexander, Ing. Agr., Andean Bean Genetics
Mukankusi Clare Mugisha (stationed in Kampala, Uganda)
Mutungu, Esther, (stationed in Nairobi, Kenya)
*Navia, Mónica, Biol., Phytopathology
Polanía, José Arnulfo, Ing. Agr. Plant Nutrition
Ricaurte, José Jaumer, Ing. Agr., MSc., Plant Nutrition
Rivera, Mariela, Ing. Agr., MSc., Plant Nutrition
Rodríguez, Isaura, Ing. Agr., Entomology
*Sangole, Noel, ERI (staioned in Lilongwe, Malawi)
Tembo, Frank (staioned in Lilongwe, Malawi)
*Wachira, Geoffrey, MSc, (stationed in Nairobi, Kenya)
Wambugu, John (stationed in Nairobi, Kenya)

Secretaries

Gómez, Julia, Plant Nutrition (25%)
Tibalikwana, Mabel, Executive Secretary (stationed in Kampala, Uganda)

Technicians

Castellanos, Guillermo, Phytopathology
Cerón, Carlos Alberto, Mesoamerican Bean Genetics
Cuasquer, Juan Bosco, Phytopathology
Díaz, Orlando, Entomology
Guerrero, Alberto Fabio, Mesoamerican and Andean Bean Genetics
* Gómez, Ivan, Germplasm Characterization
Hoyos, Agobardo, Germplasm Characterization
Joaqui, Orlando, Mesoamerican Bean Genetics
Maseko Mafuta, MacFord, (stationed in Lilongwe, Malawi)
Melo, Edifonso, Plant Nutrition
Molina Jarden, Plant Nutrition
Morales, Héctor, Entomology
Musoke, Steven, Field Technician (stationed in Kampala, Uganda)
Mwase, Archangel (stationed in Lilongwe, Malawi)
Ortíz, Guillermo, Germplasm Characterization
Otero, Martin, Plant Nutrition
Sebuliba, Sulaiman (stationed in Kampala, Uganda)
*Solarte, Olmedo, Phytopathology
Valor, Jose Flower, Entomology
Vargas, Luis Alberto, Mesoamerican Bean Genetics
*Zuleta, Jesús María, Mesoamerican Bean Genetics

*Left in 2008

Acronyms and Abbreviations used

ADRA	Adventist Development and Relief Agency
AFLP	Amplified Fragment Length Polymorphism
AHI	African Highlands Ecoregional Programme (led by ICRAF)
ALS	Angular Leaf Spot
ANOVA	Analysis of Variance
APS	American Phitopathology Society
ARC/GCRI	Agricultural Research Council, Grain Crops Research Institute, South Africa
ARI	Agricultural Research Institute
ARS	Agricultural Research Station
ASA	American Society of Agronomy
ASARECA	Association for Strengthening Agricultural Research in East and Central Africa
ASCOLFI	Asociación Colombiana de Fitopatología y Ciencias Afines
AU	Alemaya University, Ethiopia
AUDPC	Area Under Disease Progress Curve
BBK	Bembeke
BCMV	Bean Common Mosaic Virus
BCMNV	Bean Common Moasic Necrosis Virus
BEAN	Bridging Expectations, Accomplishments and further Needs
BGMV	Bean Golden Mosaic Virus
BGYMV	Bean Golden Yellow Mosaic Virus
BILFA	Bean Improvement for Low soil Fertility in Africa
BIWADA	Bean Improvement for Water Deficits in Africa
BLCrV	Bean Leaf Crumple Virus
BMGF	Bill and Melinda Gates Foundation
BMZ-GTZ	German Federal Ministry for Economic Cooperation and Development (BMZ) German Agency for Technical Cooperation (GTZ)
BOT	Board of Trustees
BSM	Bean Steam Magot
CAAS	Chinese Academy of Agricultural Sciences
CARE	Cooperative for American Remittances Everywhere
CBB	Common Bacterial Blight
CBOs	Community Based Organizations
CCF	Consolidated Conceptual Framework
CD	Congo Democratic
CENARGEN	Centro Nacional de Investigaciones en Recursos Genéticos y Biotecnología
CENIAP	Centro Nacional de Investigaciones Agropecuarias, Venezuela
CENTA	Centro Nacional de Tecnología Agropecuaria, El Salvador
CG	Consultative Group
CGIAR	Consultative Group on International Agricultural Research
CGS	Competitive Grant System
CIAL	Comité de Investigación Agrícola Local
CIALCA	Consortium for Improved Agriculture-based Livelihoods in Central Africa
CIAS	Centro de Investigaciones Agrícolas del Sureste, SEA, Dominican Republic
CIAT	Center for International Tropical Agriculture
CIDA	Canadian International Development Agency
CIFP	Centro de Investigaciones Fitoecogenéticas Pairumani, Bolivia

CIM	CIAT Malawi
CIMMYT	International Maize and Wheat Improvement Centre
CIP	Centro Internacional de la Papa, Peru
CIPRES	Centro de Investigación y Promoción de Desarrollo Rural y Social
CMAD	Community Mobilization Against Desertification
CN	Care Norway
COLCIENCIAS	Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología "Francisco José de Caldas"
CORAF/ WECARD	Conférence des Responsables de Recherche Agricole en Afrique de l'Ouest et du Centre/West and Central African Council for Agricultural Research and Development
CORFOCIAL	Corporación para el Fomento de los Comités de Investigación Agrícola Local
CORPOICA	Corporación Colombiana de Investigación Agropecuaria
COSUDE	Cooperación Suiza para el Desarrollo
CPAR	Canadian Physician for Relief and Development
CRDA	Centre Recherche de Agriculture, Haiti
CRIA	Centro Regional de Investigaciones Agrícolas
CRSP	Collaborative Research Support Project
CRS	Catholic Relief Services
CSSA	Crop Science Society of America
CTHA	Centre Technique Horticole d´Antananarivo
CTZ	Chitedze
CU	Concern Universal
CV	Coefficient of Variance
CYTED	Latin American Program for the Development of Science and Technology
DANIDA	The Danish Agency for Development Assistance
DAO	District Agricultural Office
DARTS	Department of Agricultural Research and Technical Services
DEL	Delmas
DFID	Department for International Development
DGDC	General Directorate for Development Cooperation, Belgium
DICTA	Dirección de Investigación de Ciencias y Tecnología Agrícola, Honduras
DNA	DeoxyriboNucleic Acid
DR	Democratic Republic
DRC	Democratic Republic of Congo
DRD	Directorate of Research and Development
DSI	Drought Susceptibility Index
DTF	Days to Flowering
DTM	Days to Maturity
EAP	Escuela Agrícola Panamericana, Honduras
EARO	Ethiopian Agricultural Research Organization
ECA	East and Central Africa
ECAPAPA	Eastern and Central Africa Programme for Agricultural Policy Analysis
ECABREN	Eastern and Central Africa Bean Research Network
EEA	Estación Experimental Agrícola
EIAR	Ethiopia Institute of Agricultural Research
EMBRAPA	Empresa Brasilera de Pesquisa Agropecuaria
ERI	Enabling Rural Innovation
ESA	East and Southern Africa
ETIAH	Estación Territorial de Investigaciones Agropecuarias de Holguín

FA	Farm Africa
FAIDA	(just a name in Swahili)
FANR	Food, Agriculture and Natural Resources
FAO	Food and Agriculture Organization
FARM	an NGO, Ethiopia
FC	Field capacity
FENALCE	Federación Nacional de cultivadores de Cereales
FIDAR	Fundación para la Investigación y Desarrollo Agrícola
FIPAH	Fundación para la Investigación Participativa con Agricultores de Honduras
FIPS	Farm Inputs Promotion Africa
FLS	Floury leaf spot
FONTAGRO	Fondo Regional de Tecnología Agropecuaria
FOFIFA	Centre National de la Recherche Appliqué au Développement Rural, Madagascar
GCP	Generation Challenge Program
GIS	Geographical Information System
HAAS	Harbin Agricultural Academy of Sciences
HEM	Himo Environmental Management Trust
HIV/AIDS	Human Immuno Deficiency Virus/Acquired Immune Deficiency Syndrome
HPLC	High Performance Liquid Chromatography
HRE	Harare
HRI	Horticultural Research Institute (UK)
IACR	Rothamsted (UK)
IAEA	International Atomic Energy Agency
IBFA	Ikulwe Bean Farmers Association (Uganda)
ICA	Instituto Colombiano Agropecuario
ICDPM	Integrated Crop Disease and Pest Management
ICIPE	Centre for Research in Agro-Forestry
ICRAF	International Center for Research in Agroforestry, Kenya
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnología Agrícolas, Guatemala
ICP	Inductive Coupling Plasma
IDIAF	Instituto Dominicano de Investigaciones Agropecuarias y Forestales
IDIAP	Instituto de Investigación Agropecuaria, Panama
IDRC	International Development Research Center
IIA	Instituto de Investigaciones Agrícolas
IIAM	Instituto de Investigacao Agraria, Maputo, Mozambique
IICA	Instituto Interamericano de Cooperación para la Agricultura
IITA-SARRNET	International Institute for Tropical Agriculture - Southern Africa Regional Root Crops Research Network
INCA	Instituto Nacional de Ciencias Agrícolas, Cuba
INERA	Institut National des Etudes sur la Recherche Agronomique, D.R. Congo
INHA	Instituto de Nutrición La Habana, Cuba
INIA	Instituto National de Investigacao Agronomica (Mozambique)
INIA	Instituto Nacional de Investigación Agrícola
INIAP	Instituto Nacional Autónomo de Investigaciones Agropecuarias, Ecuador
INIFAP	Instituto Nacional de Investigac. Forestales y Agropecuarias, Mexico
INM	Integrated Nutrient Management
INPRHU	Instituto de Promoción Humana
INRA	Institut National de Recherche Agronomique
INTA	Instituto Nicaragüense de Tecnología Agropecuaria

IPDM	Integrated Pest and Disease Management
IPGRI	International Plant Genetic Resources Institute
IPL	Instituto Peruano de Leguminosas de Grano
IPM	Integrated Pest Management
IPRA	Investigación Participativa en Agricultura/ Participatory Research in Agriculture of CIAT
IRRI	International Rice Research Institute, Philippines
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques du Rwanda
ISEM	Integrated Soil Ecosystem Management
ISISCAN	a complete Routine Analysis Software designed for operation of FOSS NIR insturments in lab
ITA	Instituto Técnico Agrícola
JEEP	Joint External Evaluation of PABRA
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate
KHAK	Khaki
KIS	Kisanga
LAI	Leaf area index
LSD	Least significant difference
MAC	Medium Altitude Climbers
MAFP	Ministério de Agricultura, Florestas e Pescas (República Democrática de Timor-Leste)
MAG	Ministerio de Agricultura y Ganadería
MARDI	Maruku Agricultural Research and Development Institute
MAS	Marker Assisted Selection
MASL	Meters above sea level
MATF	Maendeleo Agricultural Trust Funds
MDG	Millennium Development Goals
MEIA	Microparticles Enzymatic Immuno Assays
MIICO	Mbozi, Ileje and Isangati Consortium/foundation
MIP	Manejo Integrado de Plagas/Integrated Pest Management
MoA	Ministry of Agriculture
MT	Metric ton
MTP	Medium Term Plan
MU	Makerere University, Uganda
MW	Malawi
NAARI	Namulonge Agricultural and Animal Production Research Institute
NARC	Nazareth Agricultural Research Center
NARI	National Agricultural Research Institute
NARO	National Agricultural Research Organization, Uganda
NARS	National Agricultural Research Systems
NAV	Navy
NBPR	National Bean Research Programmes
NBPGR	National Bureau of Plant Genetic Resources
NEPAD	The New Partnership for Africa’s Development
NGOs	Non-Governmental Organizations
NIRS	Near InfraRed Spectrophotometry
NN	Non nodulating
NPP	Networks, Programs and Project,
NRI	Natural Resources Institute (UK)

NRM	Natural Resource Management
NUA	Andean Nutrition
OFDA	Office of Foreign Disaster Assistance
OPV	Open Pollinated Variety
ORE	Organization for the Rehabilitation of the Envirnoment, Haiti
ppm	parts per million
PABRA	Pan-Africa Bean Research Alliance
PADF	Pan American Development Foundation
PANNAR	Seed Company
PBS	Potato Bean Sweet
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios
PCR	Polymerase chain reaction
PHI	Pod harvest index
PM&E	Participatory Monitoring & Evaluation
PNL	Programme Nacional Legumineuse
PPB	Participatory Plant Breeding
PRGA	Participatory Research and Gender Analysis
PRIAM	Participatory Research for Improved Agroecosystem Managemente project, Africa
PROFRIZA	Proyecto Regional de Frijol para la Zona Andina
PROMPEX	Comisión para la Promoción de Exportaciones
PRONALAG	Programa Nacional de Leguminosas Alimenticias
PVS	Participatory Variety Selection
QPM	Quality Protein Maize project
QTL	Quantitative trait loci
RAZ	Resistance to *Acanthoscelides* and *Zabrotres*
RBM	Result based monitoring
REDSO/ESA	Regional Economic Development Services Office for East and Southern Africa
REU	Reach-End Users
RF	The Rockefeller Foundation
RIL	Recombinant inbred line
RM	Red Mottled
RD	Root diameter
RL	Root length
RR	Root rot
RT	Root tips
RSP	Regional Support Programme
RSSP	Rural Sector Support Program
SABRN	Southern Africa Bean Research Network
SACCAR	Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training
SADC	Southern Africa Development Council
SARBEN	Southern Africa Regional Bean Evaluation Nursery
SARBYT	Southern Africa Regional Bean Yield Trial
SARI	Selian Agricultural Research Institute, Ethiopia
SAS	Statistical Analysis System
SC	Steering Committee
SCAR	Sequence-characterized amplified regions
SDC	Swiss Development Cooperation

SEA	Secretaría de Estado de Agricultura, Dominican Republic
SENA	Servicio Nacional de Aprendizaje
SENASEM	Service National des Semences
SERIDA	Servicio Regional de Investigación y Desarrollo Agroalimentario, Spain
SGRP	Systemwide Genetic Resources Programme
SICTA	Sistema de Integración Centroamericano de Tecnología Agropecuaria
SPAD	Chlorophyll meter to determine leaf chlorophyll content
SRL	Specific root length
SSACP	Sub-Saharan Africa Challenge Program
SSSA	Seed System Security Assessment
SSSN	SADC Seed Security Network
SUG	Sugar
SWMnet	Soil water management network
t	ton
TARS	Tropical Agricultural Research Station
TILLING	Target Induced Local Lessions in Genomics
TNC	Total nonstructure carbohydrates
TPRI	Tropical Pesticides Research Institute, Tanzania
TSBF	Tropical Soils Biology and Fertility Program, Kenya
TSG	Technical Support Group
TSP	Triple Super Phosphate
TWFP	Tropical Whitefly Project
TZ	Tanzania
UAGRM	Universidad Autónoma Gabriel René Moreno
UK	United Kingdom
UMATA	Unidad Municipal de Asistencia Técnica Agropecuaria
UN	United Nations
UNA	Universidad Nacional Agraria, Nicaragua
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
Uyo	Uyole
VICARIBE	Vivero Caribeño de grano Andino
VIVA	Vivero Internacional de Volubles Andinos
VLIR-UOS	Vlaamse Interunivesitaire Raad-University Development Co-operation
WARDA	The Africa Rice Center
WECABREN	West, Eastern and Central Africa Bean Research Network
WINISI	A calibration software package from ISI
WVI	World Vision International
ZW	Zimbabwe